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Trials of a New Relative Humidity Sensor

by

Richard E. Payne
Woods Hole Oceanographic Institution

December 2004

Technical Report

Funding was provided by the National Oceanic and Atmospheric Administration under Grant Number NA17RJ1223.

Approved for public release; distribution unlimited.

Upper Ocean Processes Group
Woods Hole Oceanographic Institution
Woods Hole, MA 02543

UOP Technical Report 2004-03

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Nelson G. Hogg, Chair

Department of Physical Oceanography

Abstract

A new relative humidity and air temperature sensor, the Sensirion Model SHT1, has been thoroughly tested by the Upper Ocean Processes (UOP) group at the Woods Hole Oceanographic Institution. One-minute averages from two of the sensors, as well as a Väisälä HMP45A, were recorded for over a year. A third Sensirion sensor was kept in the laboratory and calibrated at monthly intervals with the other three sensors. The standard deviation of the difference in relative humidity between the Sensirion sensors and the Väisälä was about 2%RH. The difference in air temperature was about 0.2°C. Drift rates in relative humidity for the two Sensirion sensors were 2.7% RH/yr and -0.3% RH/yr, and in air temperature, 0.1°C/yr and 0/3°C/yr. Because one of the two Sensirion sensors deployed outside had significant variations in its calibration, the UOP group will not adopt these sensors. However, their very small size, low-cost, and low-power requirements may make them desirable for other uses.

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1. Introduction

The Upper Ocean Processes (UOP) group deploys a suite of meteorological modules on ships and buoys, which, with the sensors that have been selected for them, record climate quality data. From the beginning, the UOP group has been alert for improved sensors. New versions of the Väisälä relative humidity sensor and several barometric pressure sensors have been investigated for possible use in the ASIMET modules. In 2002, a new relative humidity sensor developed and manufactured in Switzerland by a new company, Sensirion, was discovered. The sales agent in the United States for Sensirion is Onset Computer Corporation in Bourne, Massachusetts.

2. Sensors

To make trials simple, Sensirion sells a kit with a supply power, a digital communications board and several sample sensors for $300. The UOP group purchased three, packaging two in IMET titanium cases and keeping the third inside the laboratory as a control. Figure 1 is a photo of the sensor package version, which was tested as installed in a plastic mount originally designed for Väisälä sensors. The mount includes a porous polyethylene plastic shield, which protects the sensor from rain and dirt. The Sensirion sensor is small and contains a relative humidity (RH) sensor, an air temperature (AT) sensor, a processor and memory, and digital communications hardware. It is capable of storing calibration coefficients, computing RH and AT in engineering units and responding to digital requests for data. The sensor alone, without the power supply and communications board costs approximately $30. Appendix A contains the specification sheet from Sensirion. Sensirion lists two models in the configuration used, SHT11 and SHT15, that differ only in their specified accuracies. The stated accuracies are given in Table 1.

Table 1: Specifications for SHT11 and SHT15 sensors.

Model	RH Range	T Range	RH accuracy	T accuracy
SHT11	0-100%RH	-40 to 120°C	±3.5%RH	±0.5°C @ 25°C
SHT15	0-100%RH	-40 to 120°C	±2 %RH	±0.4°C @ 5-40°C

3. The Experiment

In November 2002, one Sensirion SHT11 sensor (S15002) and one SHT15 sensor (S15001) with their communications boards were mounted in two ASIMET module titanium cases at the tower test site as shown in Figure 2. Two DOS computers were mounted in a shed behind the mounting rack and cables run to them. A QuickBasic program on each PC put the sensor in automatic output mode, yielding a data record approximately 85 times per minute. The program accumulated the data, recording one-minute averages. Raw counts were recorded instead of computed parameters in order to have flexibility in applying calibration constants. Also mounted on the rack was an

ASIMET relative humidity module, serial number HRH205, containing a Väisälä HMP45A sensor.
All three sensors were protected from solar radiation by multiplate shields, manufactured by R. M. Young. The ASIMET module recorded one-minute averages internally, which were used as a comparison standard. One Sensirion sensor, S15003 (SHT15), was kept in the laboratory through the whole field period and calibrated with the field sensors to look for different aging in the field sensors.

At approximately weekly intervals the data files were retrieved from the DOS computers, and at approximately monthly intervals all three units were brought inside, the data down-loaded from the HRH205 module, and all sensors calibrated. The new calibration constants were entered into the HRH205 module so that its readings would be as accurate as possible. The SHT15 kept in the lab (S15003) failed during the 25 September 2003 temperature calibration due to flooding in the water bath, and it did not work again.

Figures 3 and 4 show hourly averages of the relative humidity and air temperature, respectively, from the three units for the whole year. There are two major gaps: during the first gap, year day 368-402, the HRH205 failed to record data; during the second, year day 453-499, incorrect air temperature constants were entered into the HRH205.

4. Calibrations

All three Sensirion sensors and the Väisälä sensor (with its module electronics) were calibrated for relative humidity in the Thunder Scientific Model 2500 calibration chamber. This has an accuracy of ±0.5%RH and a range of 10-95%RH. They were also calibrated for temperature over the range 0-35°C in a Hart calibration water bath using a Seabird Electronics Model SBE35 temperature standard, which has an absolute accuracy of 1mK. In total there were 11 calibrations at approximately monthly intervals.

5. Time Series Results

The UOP group is interested in both the accuracy of the Sensirion sensors relative to the Väisälä HMP45A and their long-term stability. By revising the HRH205 constants with each calibration we expected to avoid any problems with long-term stability of the Väisälä sensor. The Sensirion data were processed using the initial calibration, October 2-3, 2002, in order to look at the long-term drift. Because the Väisälä HMP45A was found to have a fairly noisy air temperature signal, only one-hour averaged data were used in the analysis.

For an overall view, we will ignore the variation with time and will look at the scatter plots of the whole data set. Figures 5-8 are plots of HRH205 vs. the Sensirion sensors. Table 2 shows the equations and standard deviations of the fits.

Table 2: Statistics of fit of scatter plots.

Plot	Par	Sensor	Fit Equation	Std. Dev.
Fig. 5	RH	S15001(SHT15)	$RH_{HRH205} = -2.05 + 0.95623 * RH_{S15001}$	1.76%RH
Fig. 6	RH	S15002(SHT11)	$RH_{HRH205} = -3.88 + 1.00249 * RH_{S15002}$	2.01%RH
Fig. 7	AT	S15001(SHT15)	$AT_{HRH205} = -0.19 + 0.99941 * AT_{S15001}$	0.17°C
Fig. 8	AT	S15002(SHT11)	$AT_{HRH205} = -0.51 + 0.98845 * AT_{S15002}$	0.21°C

Overall, then, the Sensirion data fit the Väisälä data within approximately 2%RH and 0.2°C. Since these numbers are within the accuracy claims of both Sensirion and Väisälä, they probably represent the accuracy with which the two sensors can be compared under field conditions.

Looking at it a different way, Figures 9-12 show the time series of the differences with HRH205 with a least squares linear fit of difference to year day. Table 3 summarizes the results.

Table 3: Drift relative to HRH205.

Plot	Par	Sensor	Fit equation	Std. Dev.	Drift Rate
Fig. 9	RH	S15001	$\Delta RH = 2.01 + 0.00728 * YD$	1.77%RH	2.7%RH/yr
Fig. 10	RH	S15002	$\Delta RH = 4.09 - 7.95E\text{-}4 * YD$	2.01%RH	-0.3%RH/yr
Fig. 11	AT	S15001	$\Delta AT = 0.26 - 1.35E\text{-}4 * YD$	0.17°C	0.1°C/yr
Fig. 12	AT	S15002	$\Delta AT = 0.19 + 8.81E\text{-}4 * YD$	0.22°C	0.3°C/yr

Only S15001 RH has a significant drift rate.

6. Calibration Shifts

We can also look at the drift in calibrations. To do this, a set of nominal counts were computed. These yield the nominal calibration relative humidity values when substituted into the calibration equation derived for the sensor from the first calibration. This was done at 10%RH intervals from 20% to 90%RH, and at 5°C intervals from 0°C to 35°C. Using these count values, relative humidity was computed from the other calibrations for each sensor. Figures 13-16 are plots of the difference between the relative humidity values computed from the nominal counts and the nominal humidity values (relative humidity difference) against relative humidity. S15001 and S15002 show little change at low values of relative humidity, but their response tends to decrease through the test period. S15003 has a somewhat similar behavior, but the differences do not get as large (recall that S15003 was kept in the laboratory). The Väisälä in HRH205 varied much less, and less systematically, over the course of the comparison.

Figures 17-20 show another way of looking at the same numbers, plotting relative humidity difference against calibration date. Again, Figures 17 and 18 show that S15001 and S15002 had differences, which increased with time and increasing values of relative humidity. In Figure 19, S15003 behaves similarly but to a smaller degree. In Figure 20, the Väisälä sensor in HRH205 has a smaller shift, which does not vary systematically with date or relative humidity value.

Figures 21-24 are similar to Figures 13-16 except for air temperature. Sensor S15001, in Figure 21, has low drift and does not show a consistent pattern. Sensor S15003, in Figure 22, shows a consistent, although not monotonic, shift in calibration with date. Except for a bad point in the April 2003 calibration of S15003, it shows less than a 0.1°C variation in calibration through its last calibration in August 2003. The Väisälä in HRH205 shows 0.2°C or less variation in temperature calibration through the whole year.

Figures 25-28 show the calibrations vs. calibration date for temperature, similar to Figures 17-20 for relative humidity. For S15001, calibration variation is highest for the January to May 2003 period and decreases toward the end of the deployment. S15002 also shows maximum variation in the middle of the year. With the exception of one bad point, S15003 has low variation through the whole year. HRH205 has minimum variation through the middle of the year.

7. Conclusion

Of the three Sensirion sensors, the one kept inside and one of the two deployed outside showed excellent calibration stability and accuracy in both relative humidity and temperature. However, the S15002 had significant variations in calibration. Because of the experience with this sensor, the UOP group will not adopt the Sensirion sensor for the ASIMET HRH module. For users with more modest or shorter term accuracy requirements, the Sensirion SHT11 or SHT15 might well be worth looking at. Although communications circuitry and software must be developed for an embedded application, the sensors themselves cost approximately $30 each. Their very small size might be appealing in some applications.

8. Acknowledgement

Funding was through the National Oceanic and Atmospheric Administration, Cooperative Institute for Climate and Ocean Research, Grant No. NA17RJ1223.

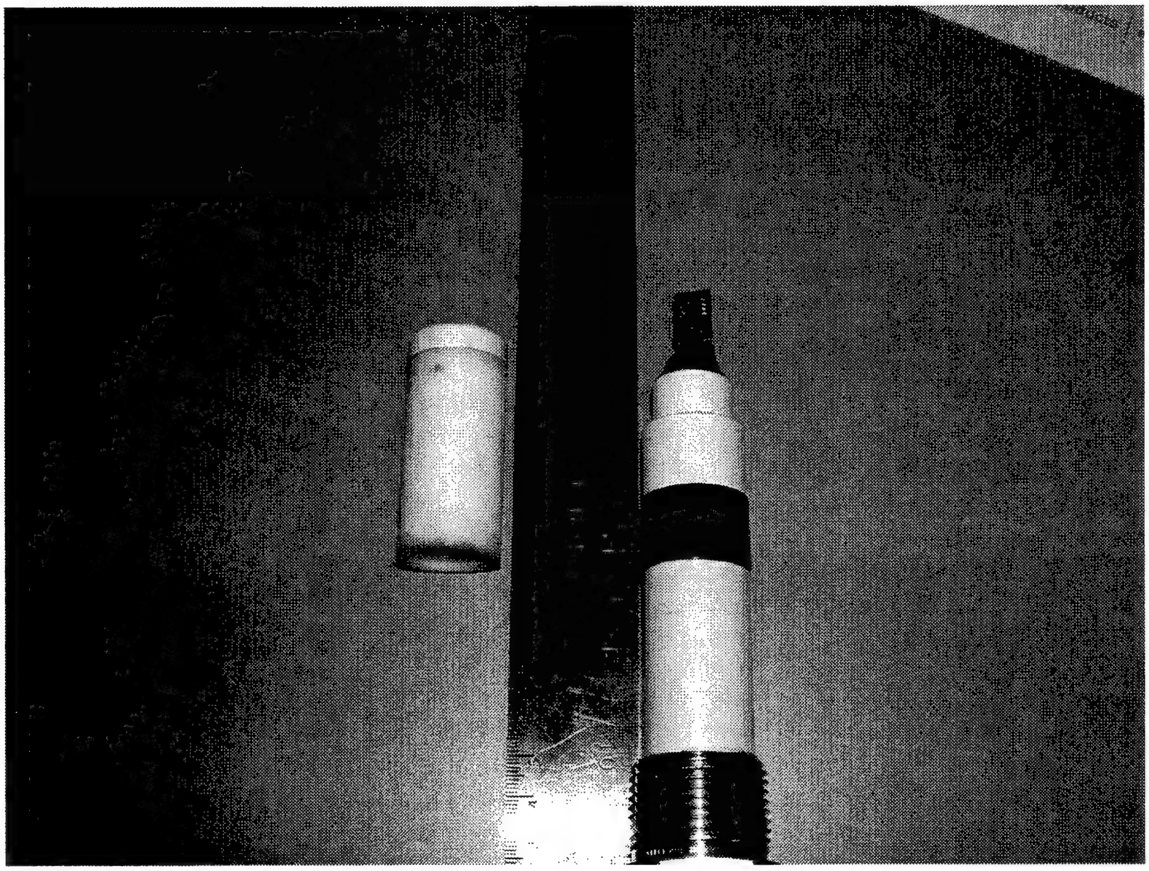


Figure 1: Sensirion sensor in plastic housing with porous cap.

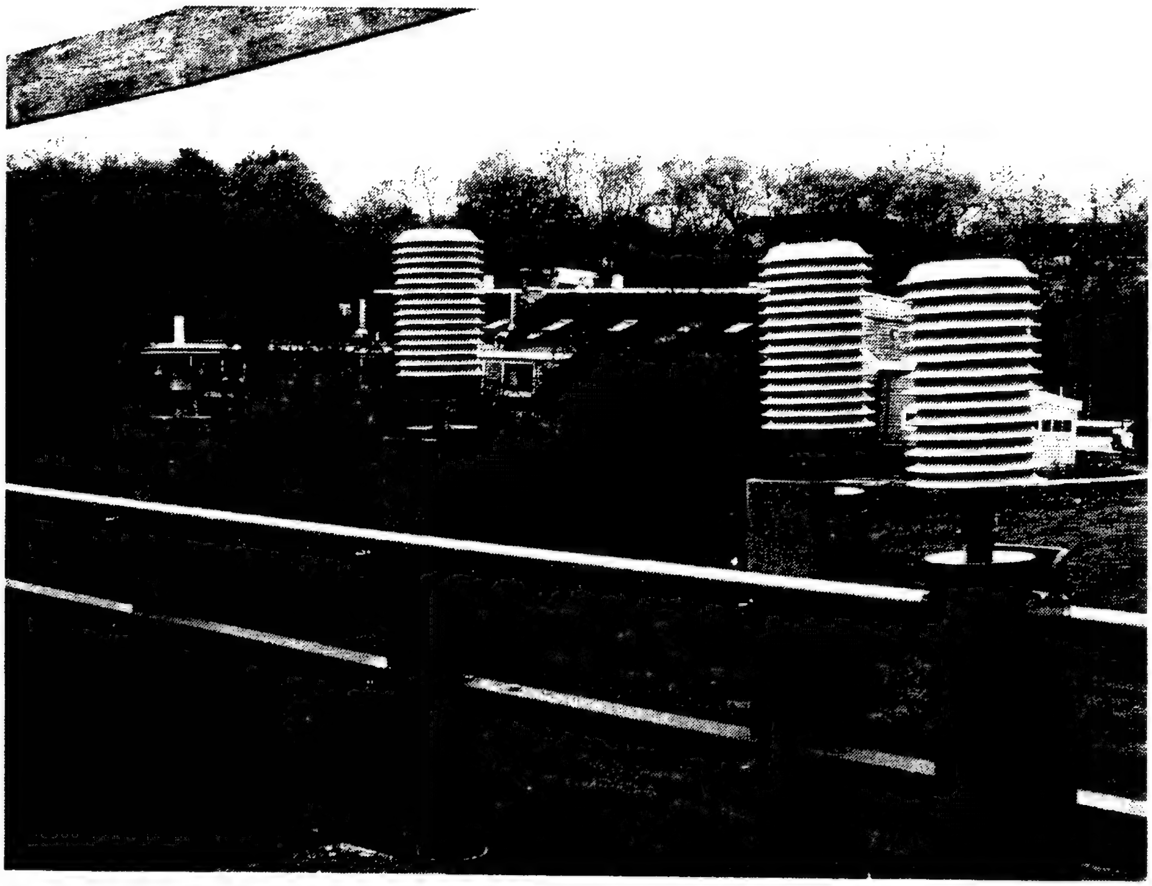


Figure 2: Two Sensirion sensors and one Väisälä sensor mounted for field tests.

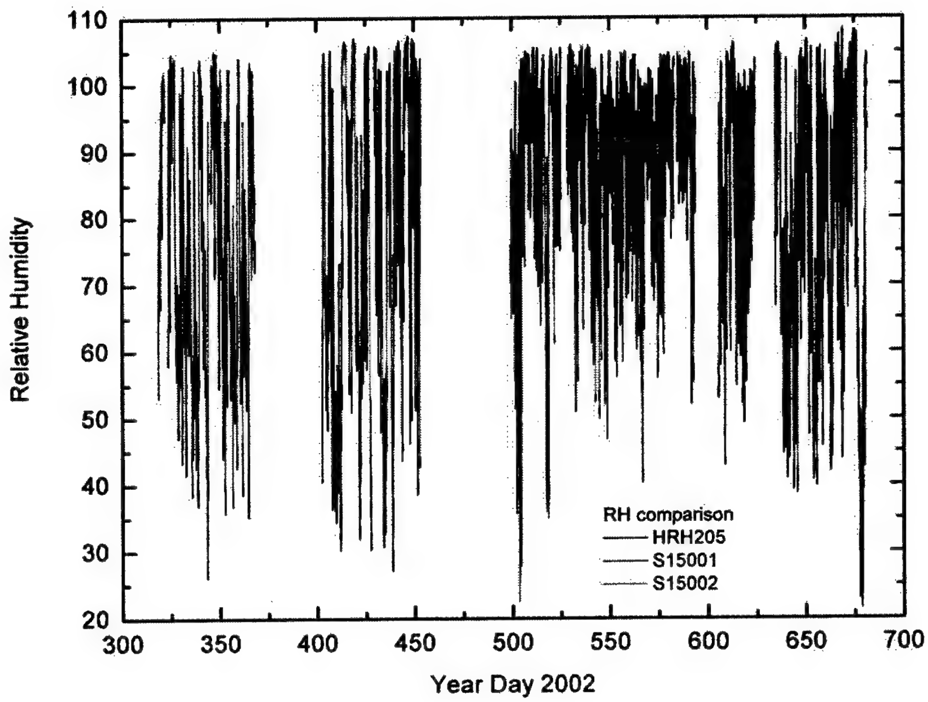


Figure 3: Relative humidity vs. time for the two field Sensirion and the Väisälä sensors.

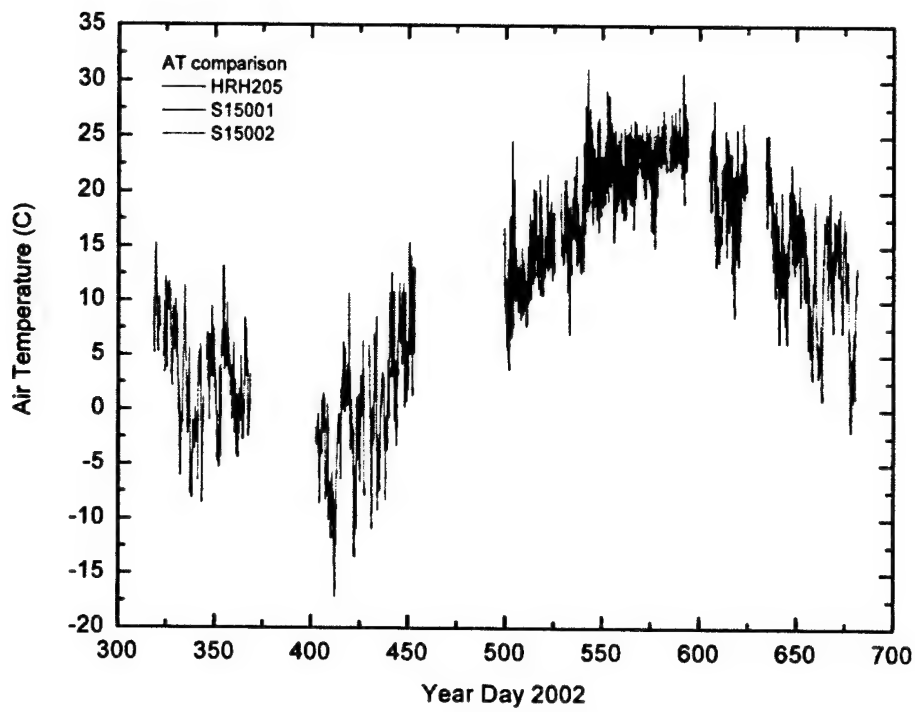


Figure 4: Air temperature vs. time for the two field Sensirion and the Väisälä sensors.

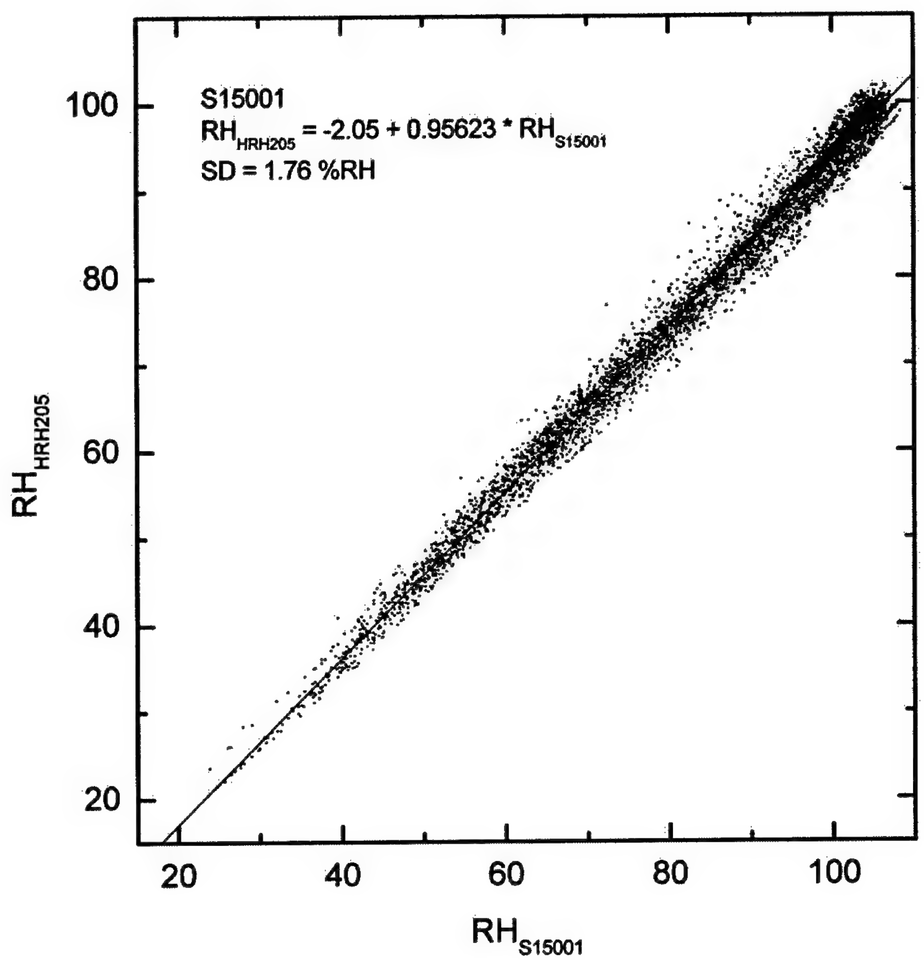


Figure 5: Scatter plot of relative humidity field data, Väisälä vs. S15001.

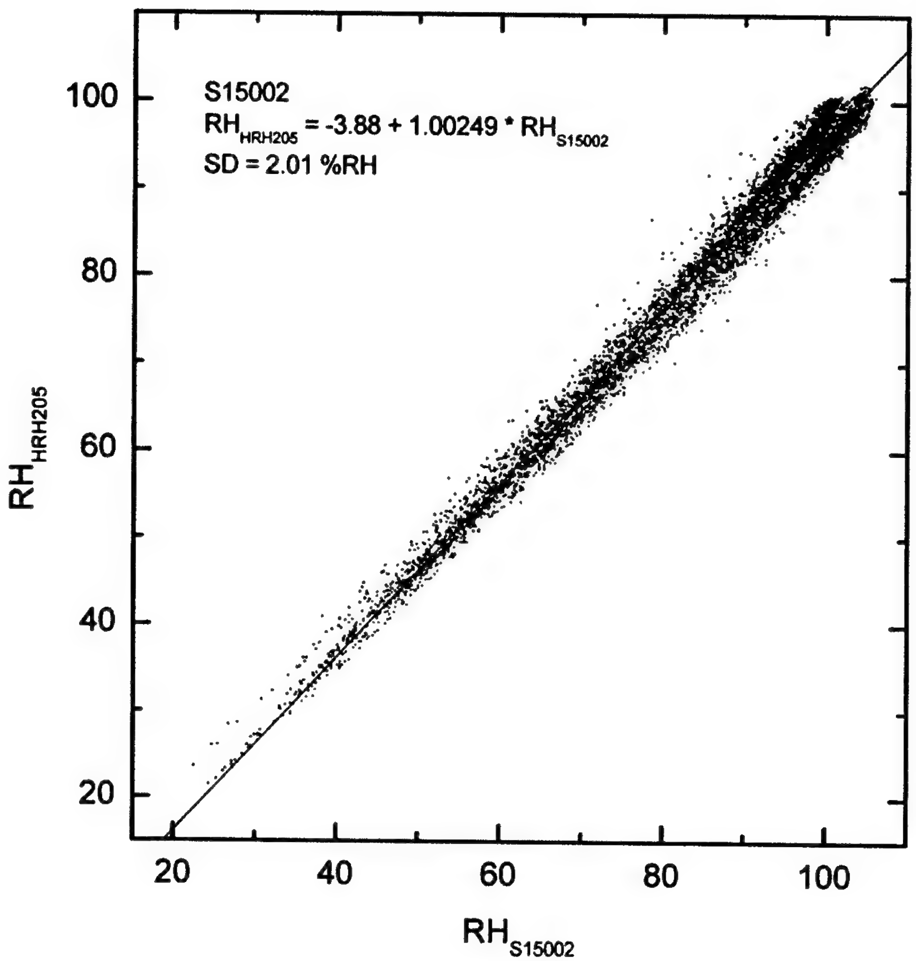


Figure 6: Scatter plot of relative humidity field data, Väisälä vs. S15002.

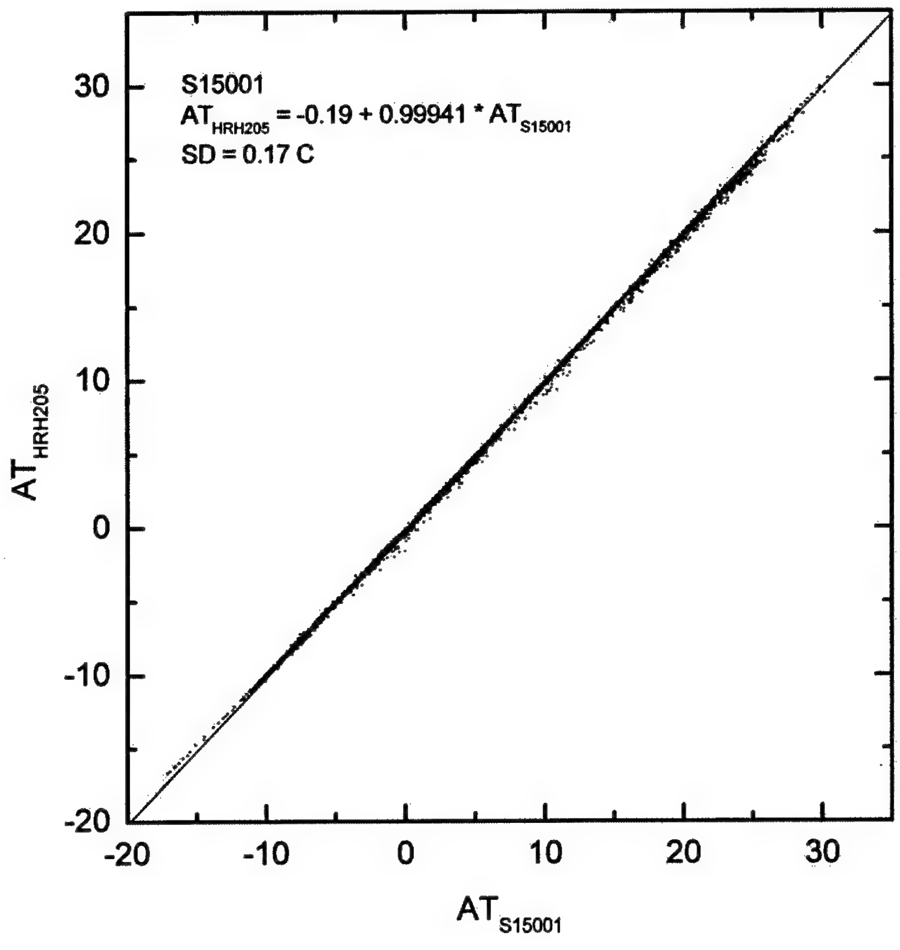


Figure 7: Scatter plot of air temperature field data, Väisälä vs. S15001.

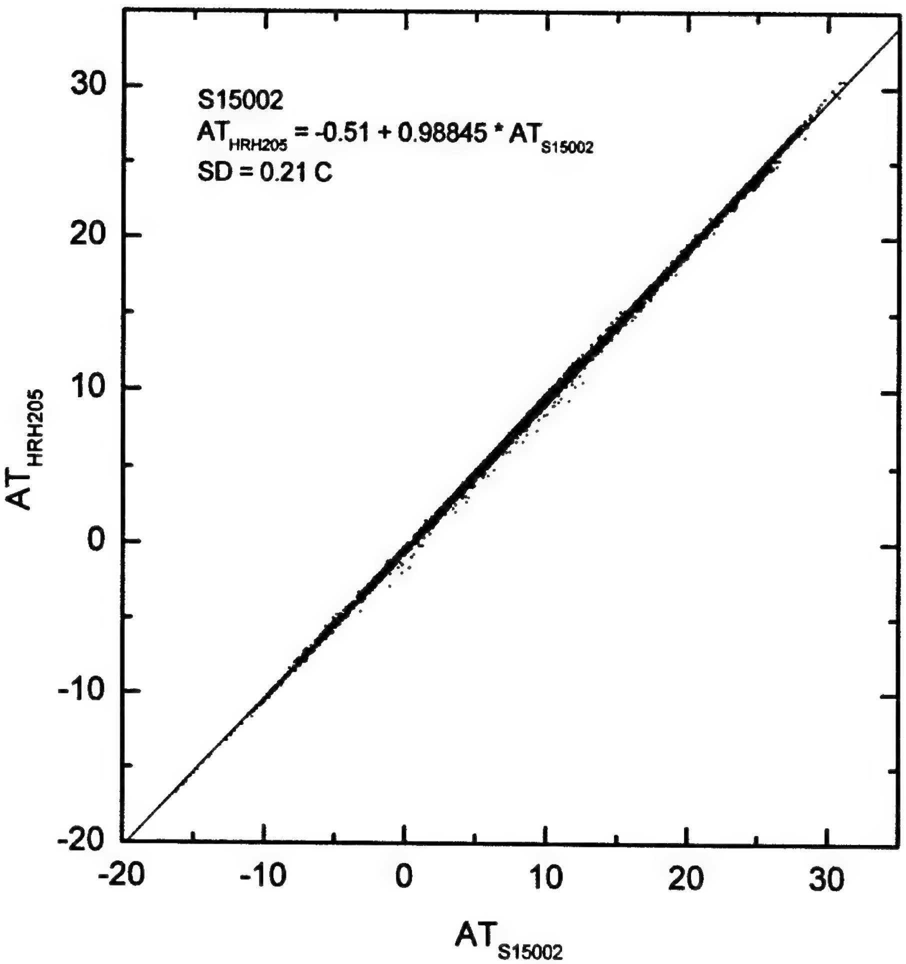


Figure 8: Scatter plot of air temperature field data, Väisälä vs. S15002.

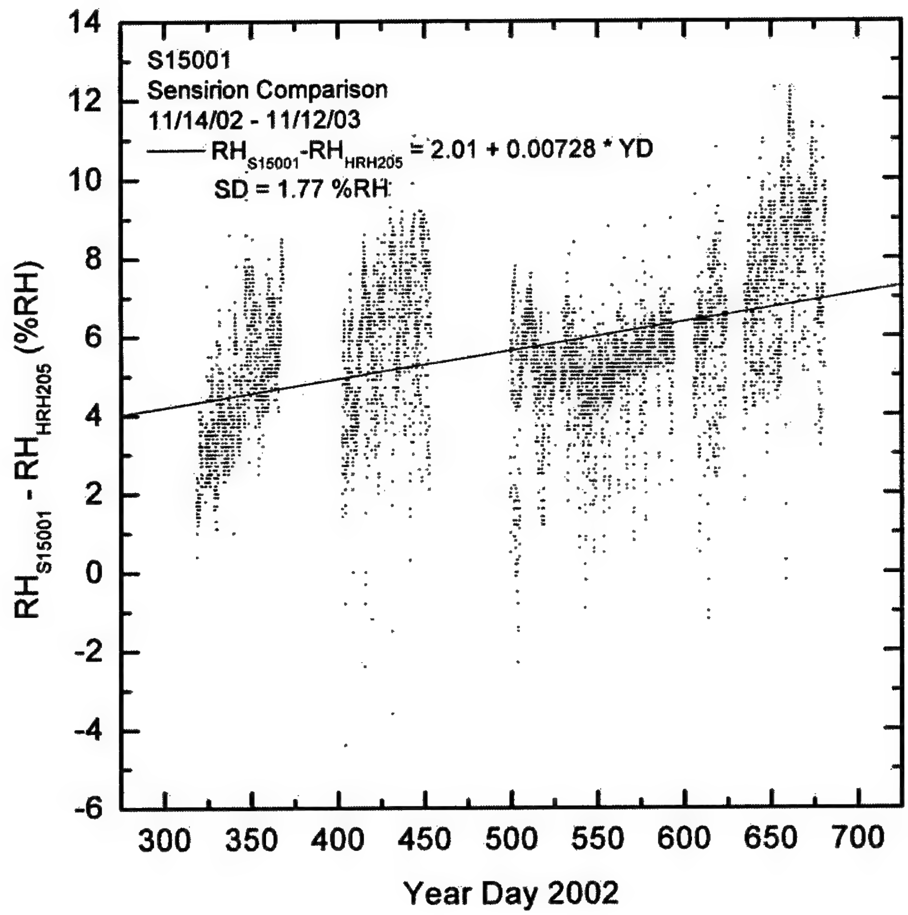


Figure 9: Relative humidity S15001 - Väisälä difference.

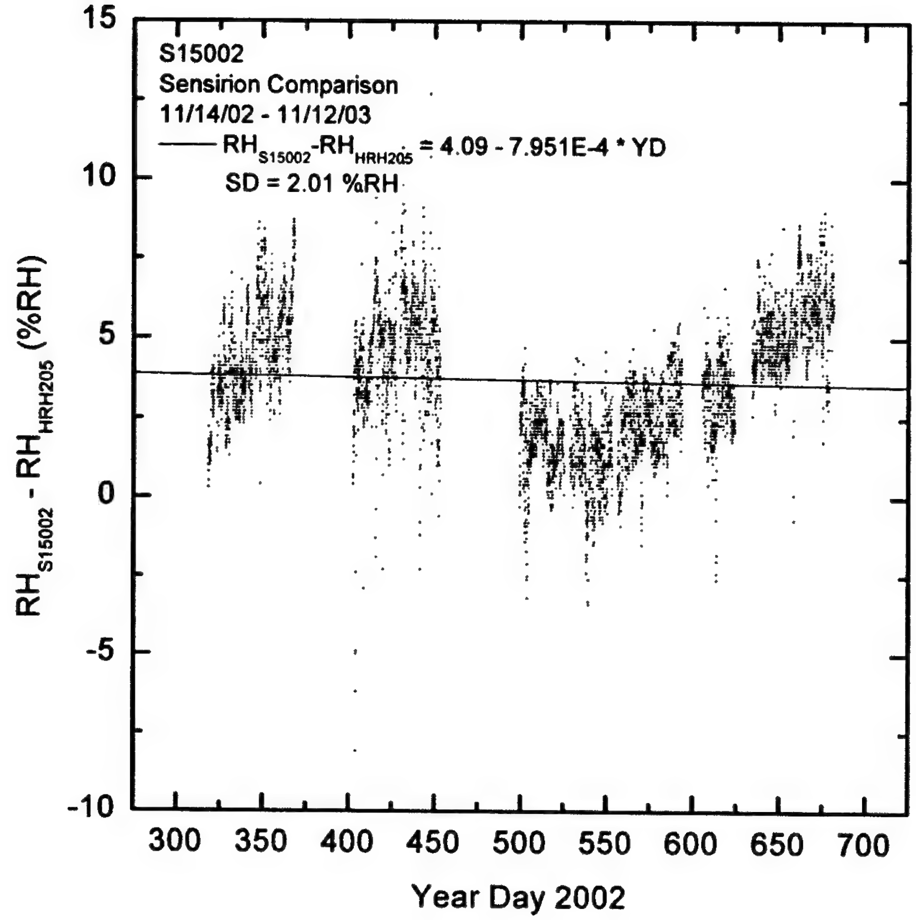


Figure 10: Relative humidity S15002 - Väisälä difference.

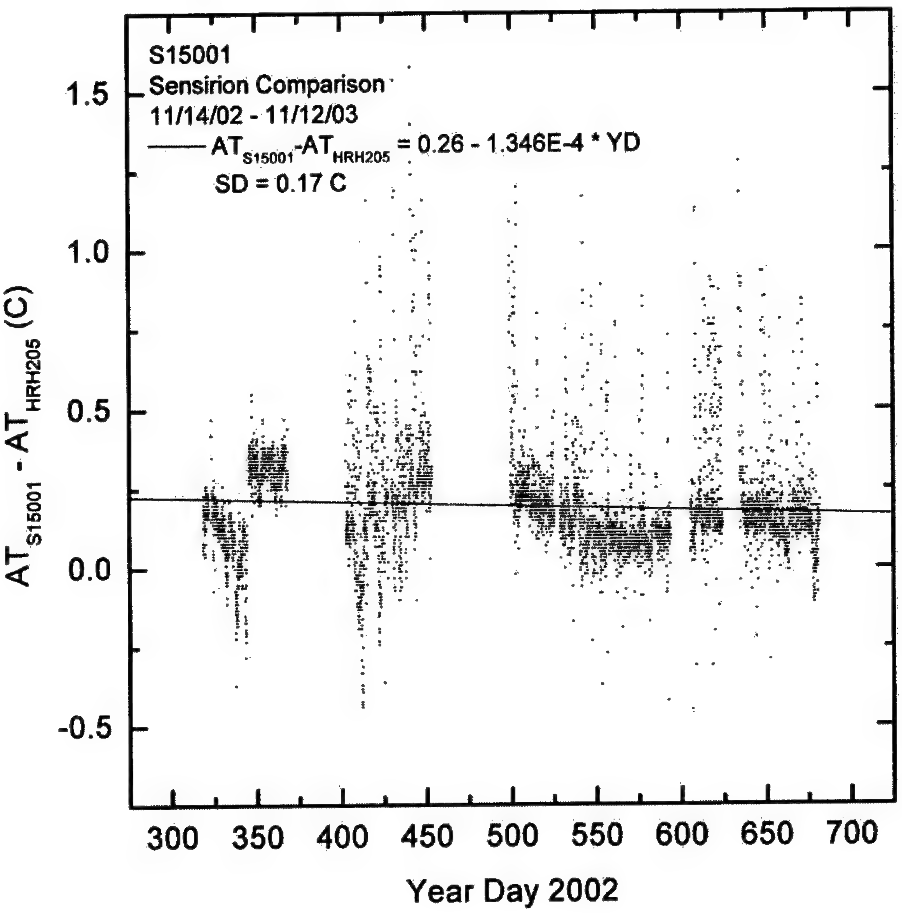


Figure 11: Air temperature S15001 - Väisälä difference.

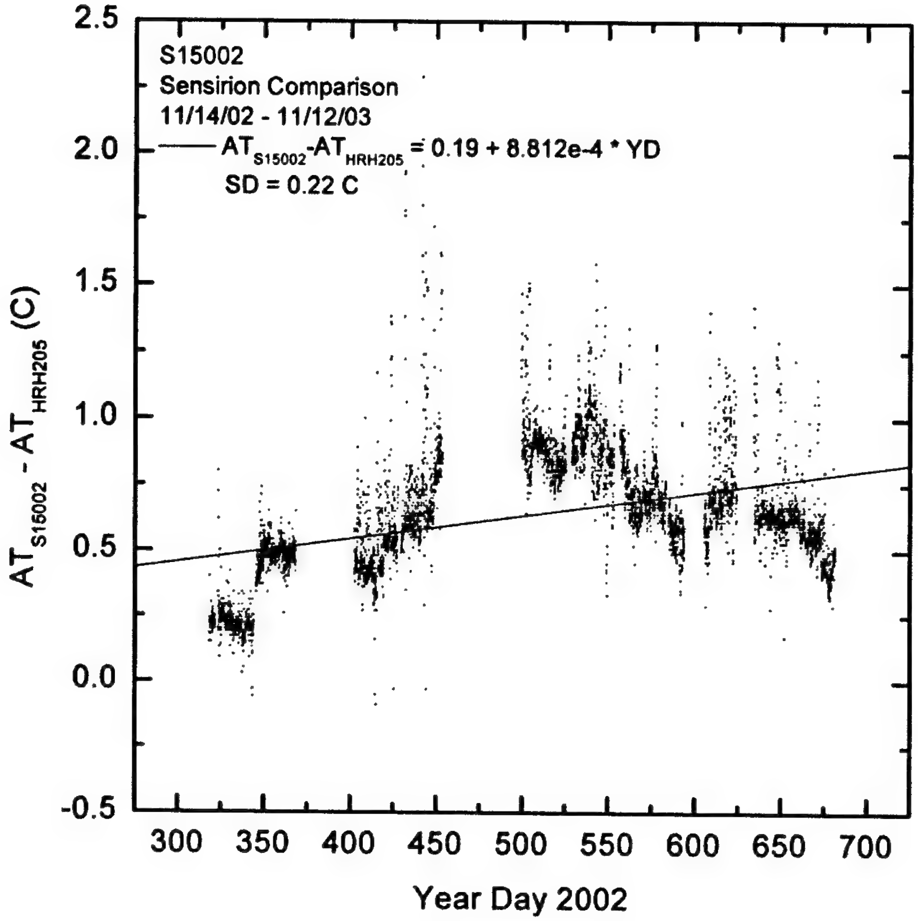


Figure 12: Air temperature S15002 - Väisälä difference.

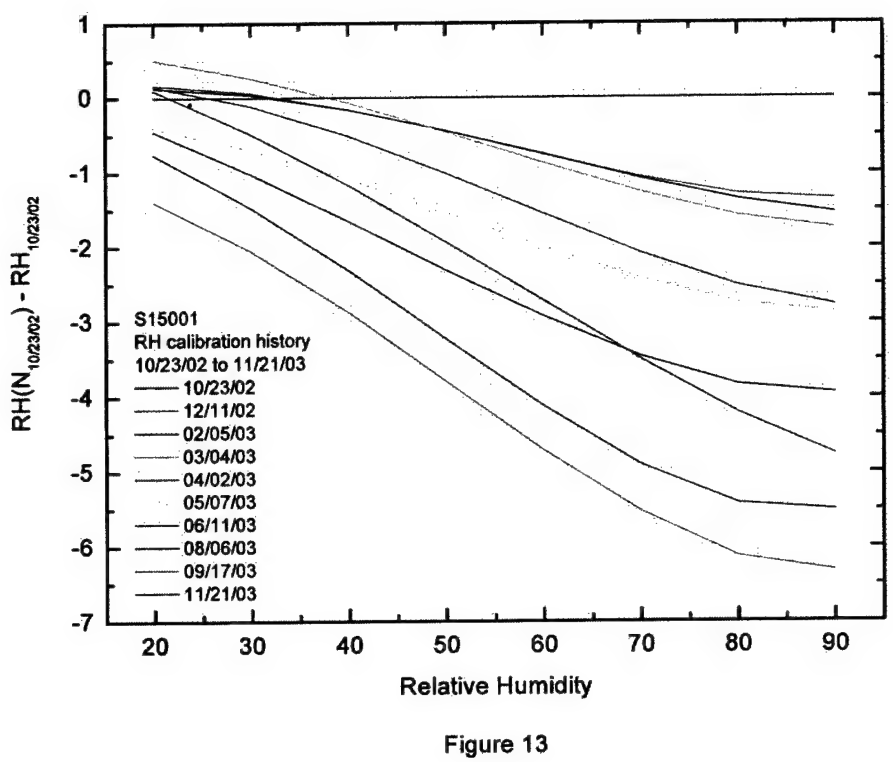


Figure 13: S15001 relative humidity calibration history vs. relative humidity.

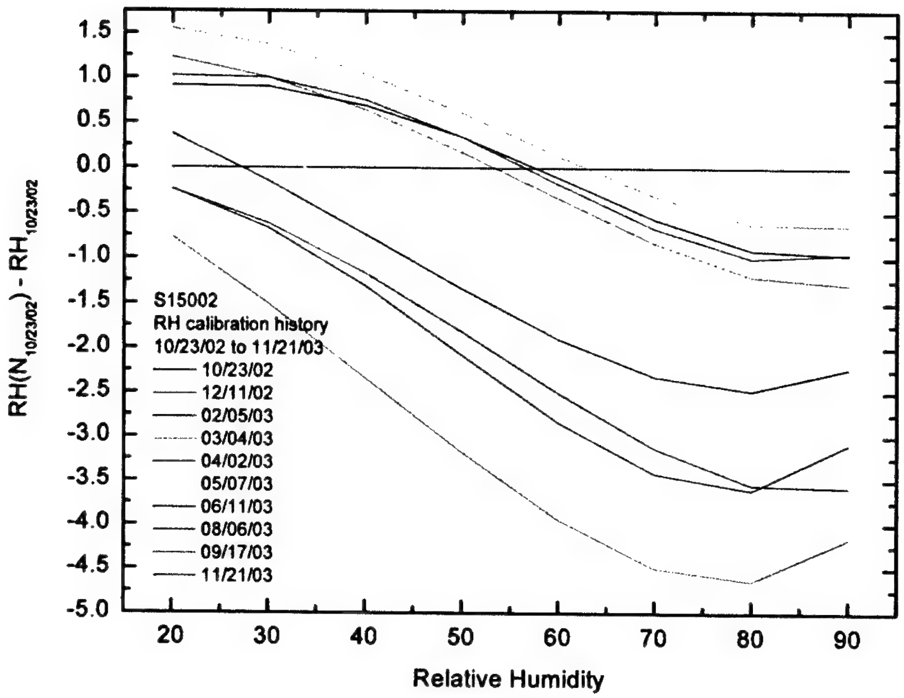


Figure 14

Figure 14: S15002 relative humidity calibration history vs. relative humidity.

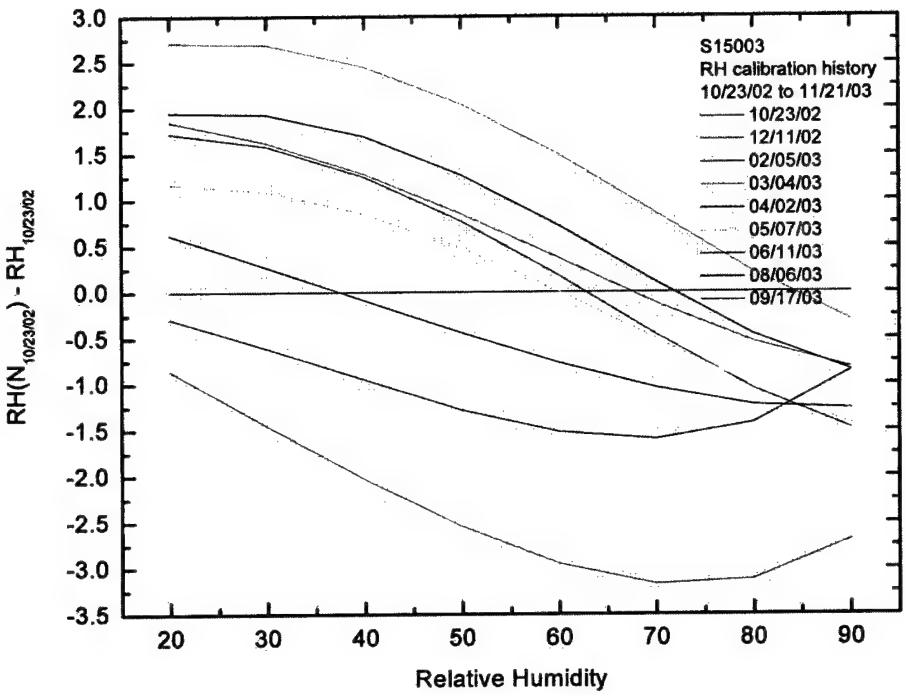


Figure 15

Figure 15: S15003 relative humidity calibration history vs. relative humidity.

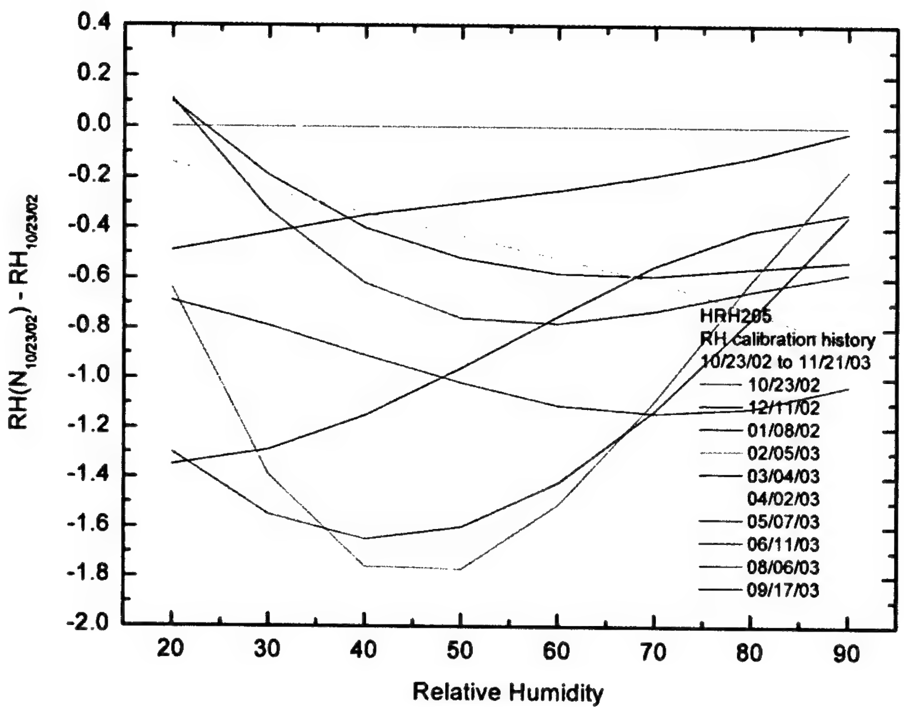


Figure 16

Figure 16: Väisälä relative humidity calibration history vs. relative humidity.

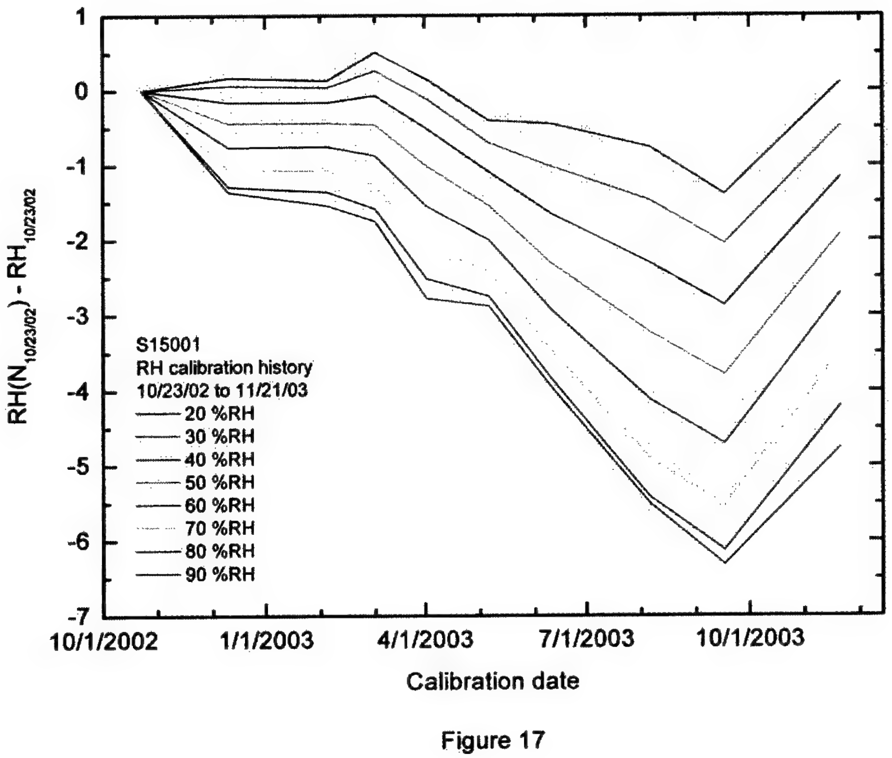


Figure 17: S15001 relative humidity calibration history vs. time.

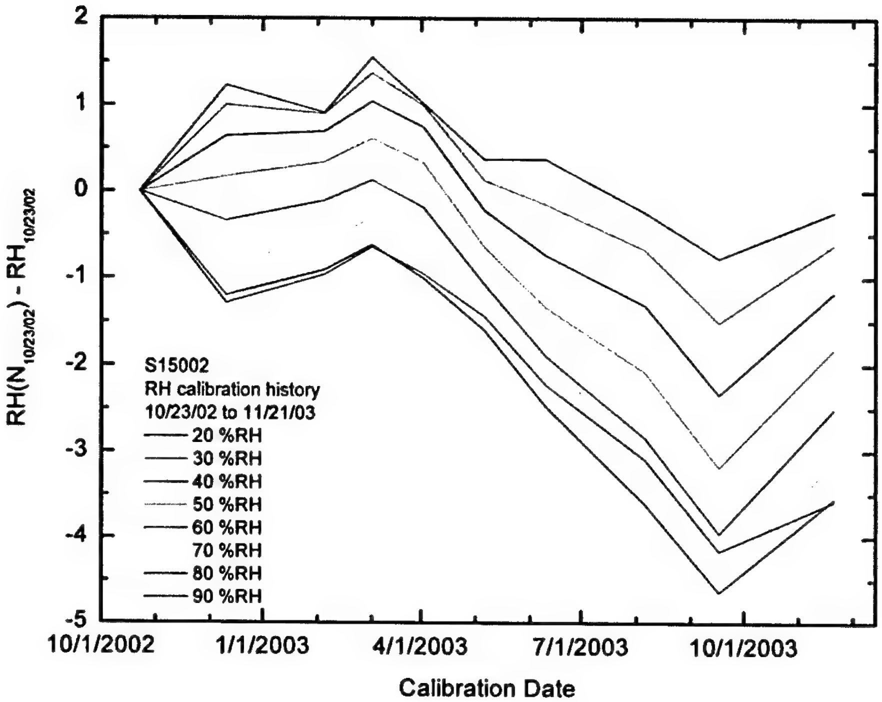


Figure 18

Figure 18: S15002 relative humidity calibration history vs. time.

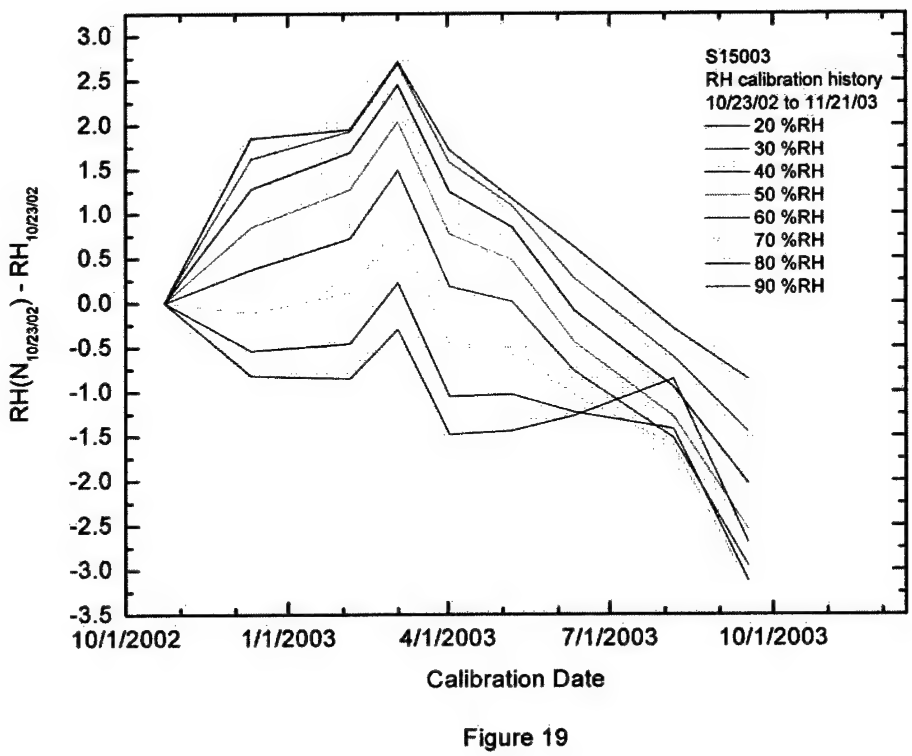


Figure 19: S15003 relative humidity calibration history vs. time.

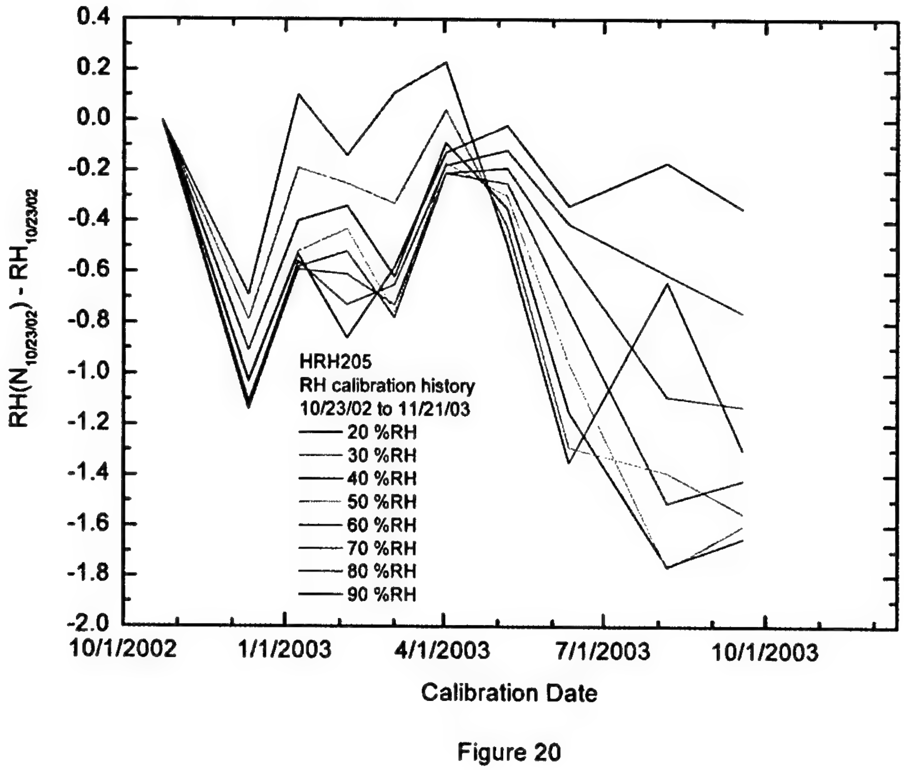


Figure 20: Väisälä relative humidity calibration history vs. time.

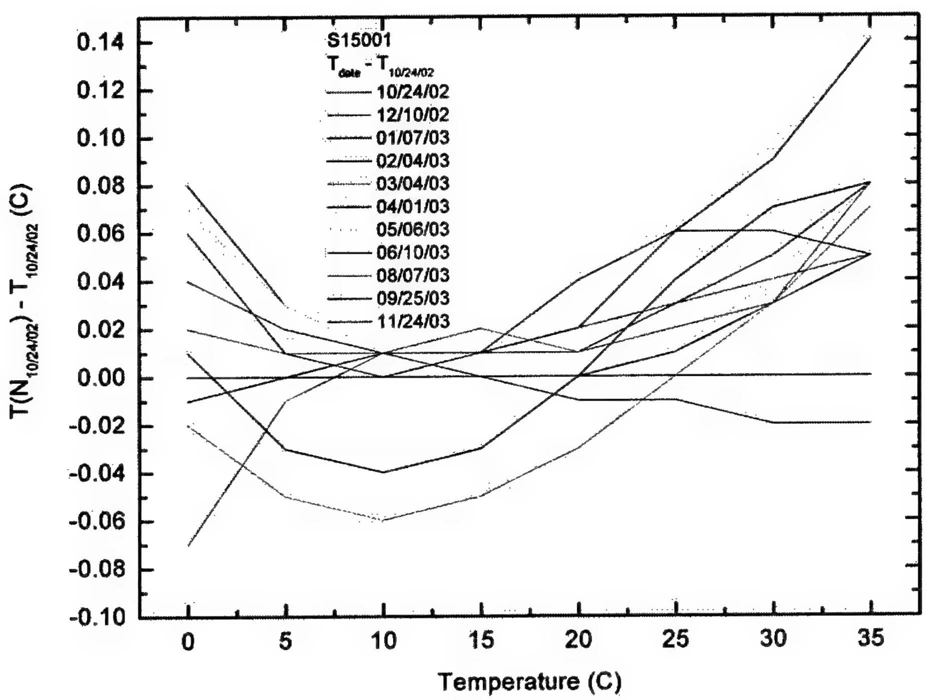


Figure 21

Figure 21: S15001 air temperature calibration history vs. relative humidity.

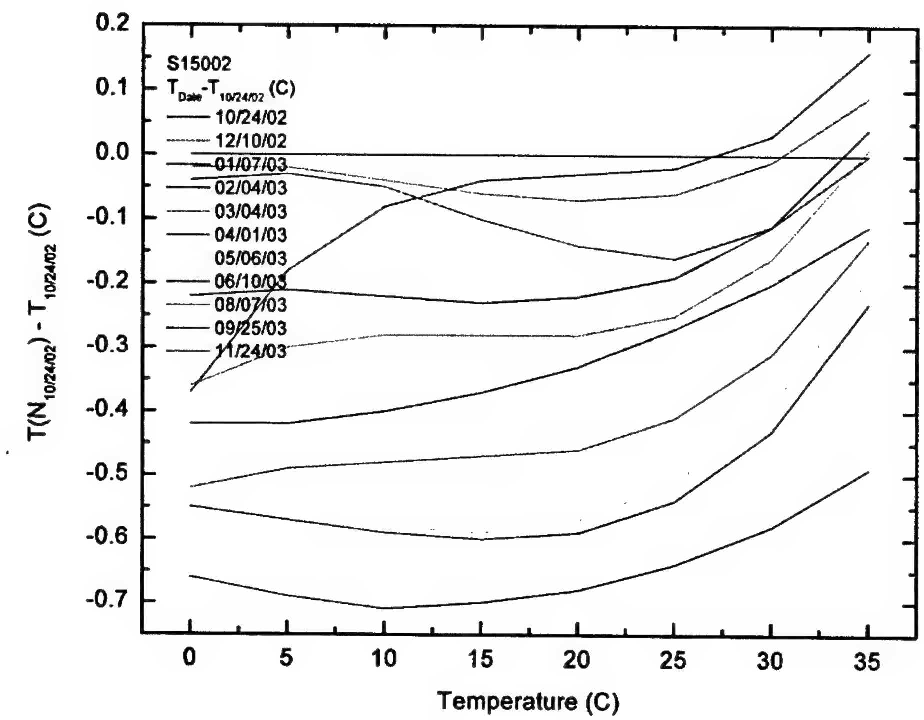


Figure 22

Figure 22: S15002 air temperature calibration history vs. relative humidity.

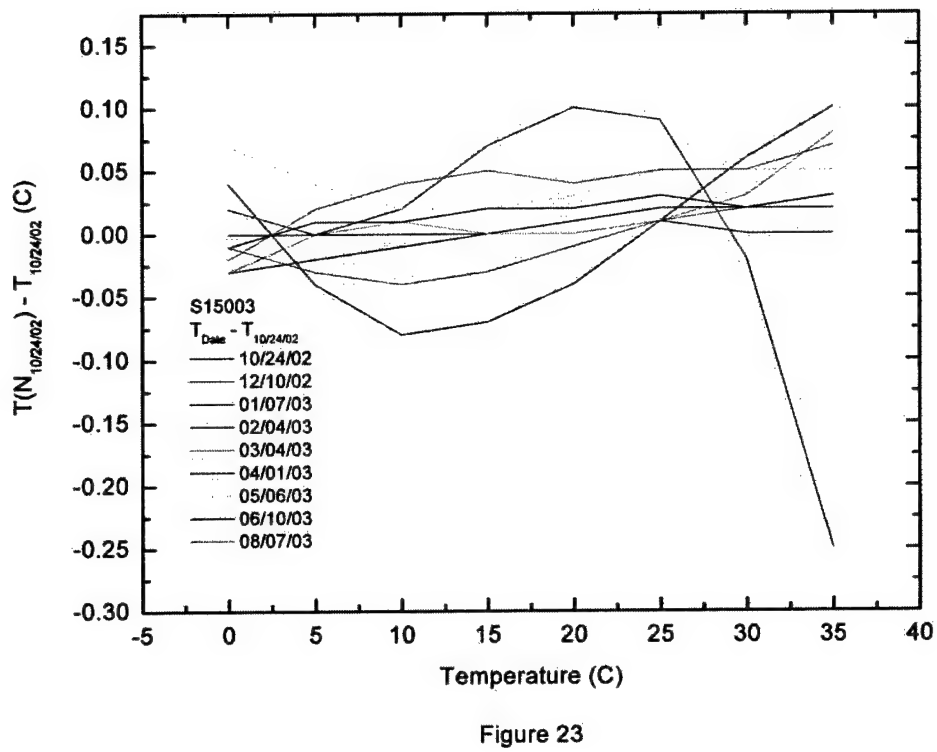


Figure 23: S15003 air temperature calibration history vs. relative humidity.

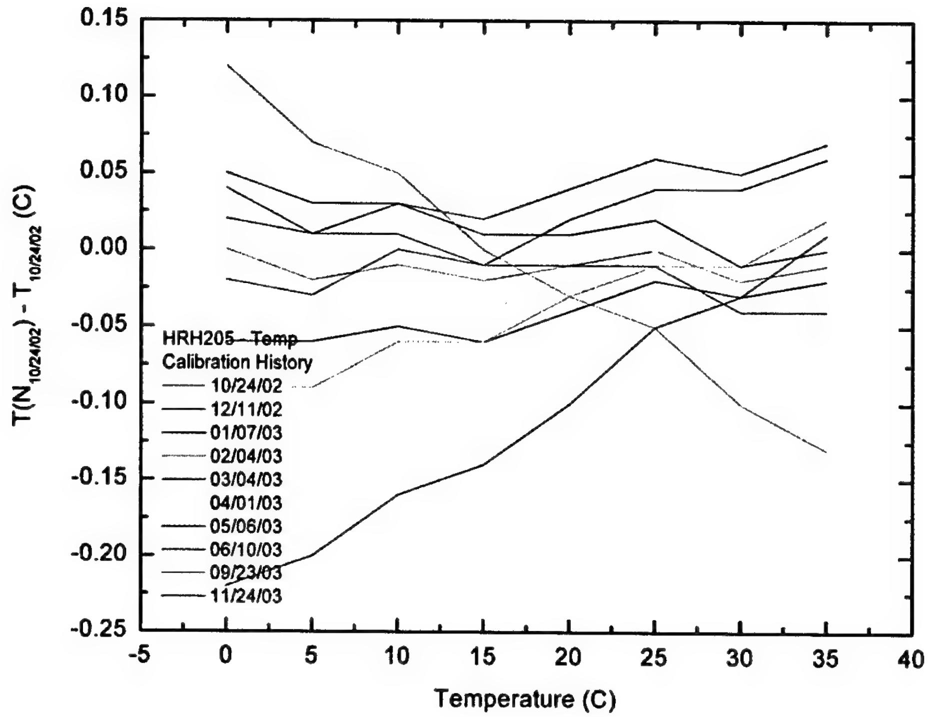


Figure 24

Figure 24: Väisälä air temperature calibration history vs. relative humidity.

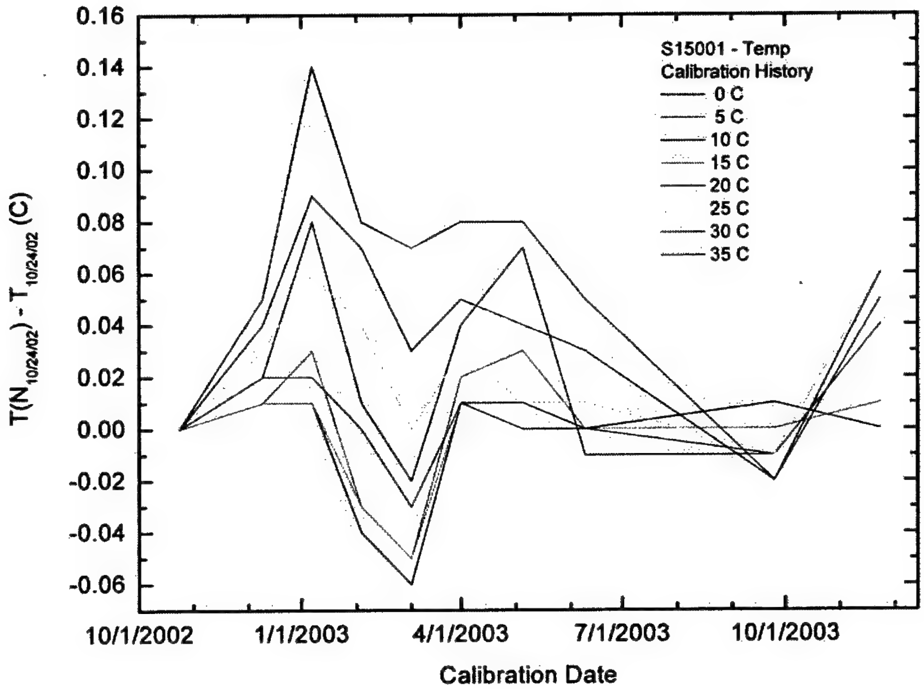


Figure 25

Figure 25: S15001 air temperature calibration history vs. time.

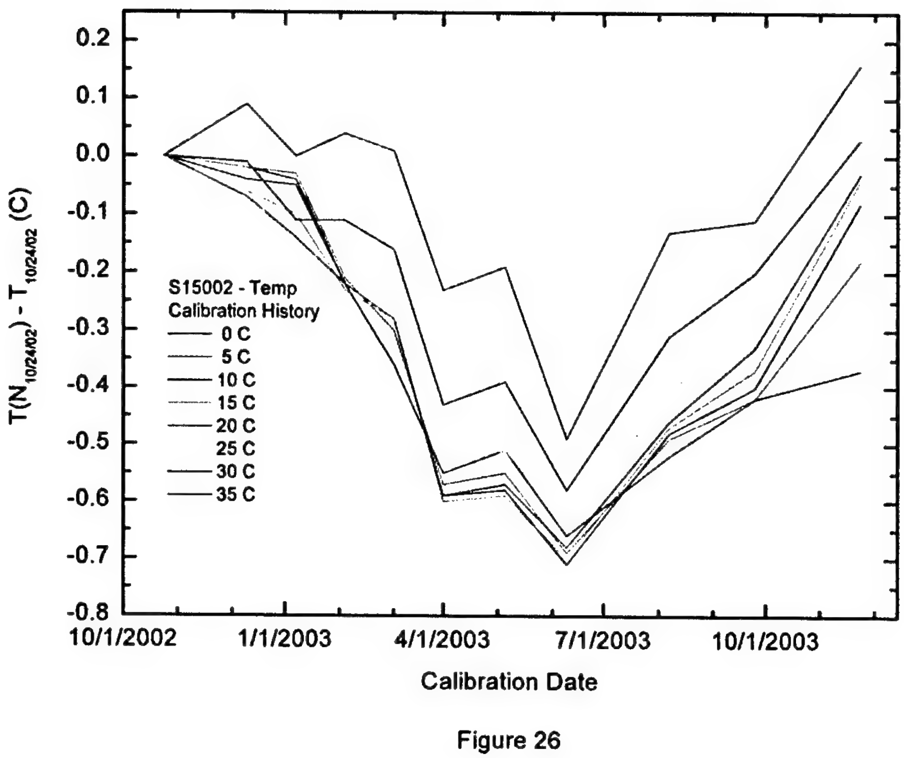


Figure 26: S15002 air temperature calibration history vs. time.

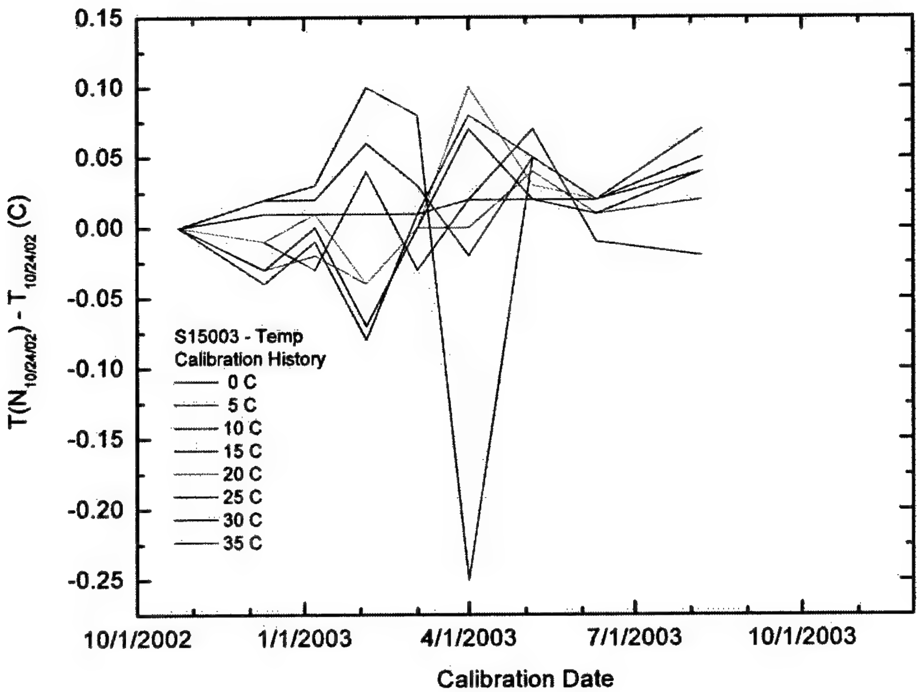


Figure 27

Figure 27: S15003 air temperature calibration history vs. time.

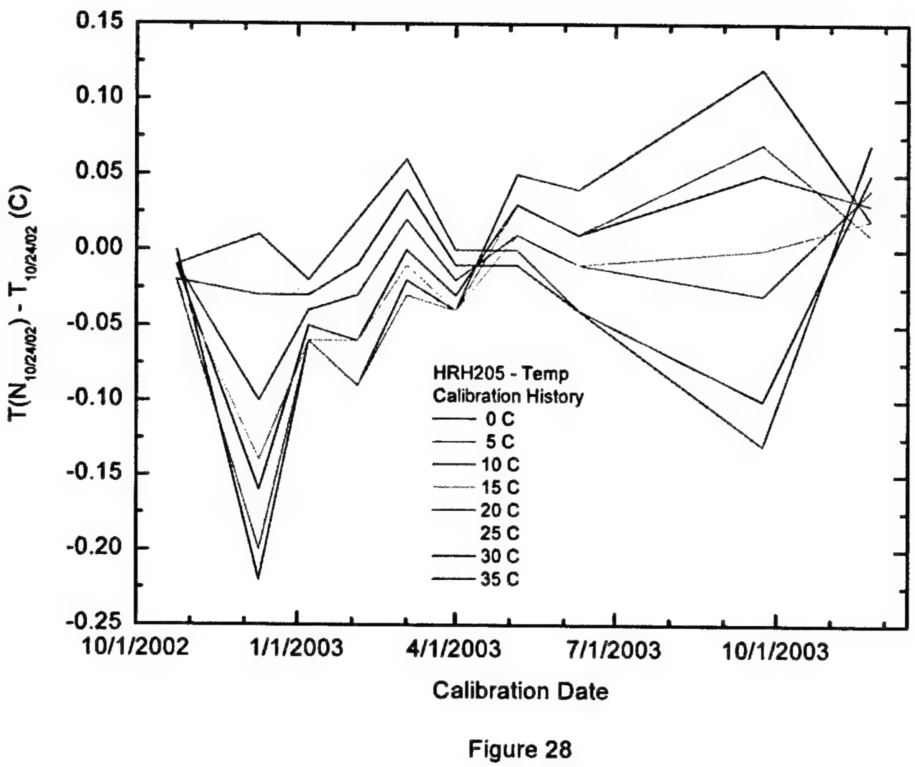


Figure 28: Väisälä air temperature calibration history vs. time.

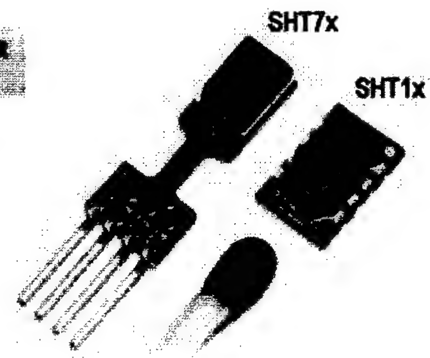
Appendix A

SENSIRION
THE SENSOR COMPANY

SHT1x / SHT7x

Humidity & Temperature Sensor

Evaluation Kit Available



_ Relative humidity and temperature sensors
_ Dew point
_ Fully calibrated, digital output
_ Excellent long-term stability
_ No external components required
_ Ultra low power consumption
_ Surface mountable or 4-pin fully interchangeable
_ Small size
_ Automatic power down

SHT1x / SHT7x Product Summary

The SHTxx is a single chip relative humidity and temperature multi sensor module comprising a calibrated digital output. Application of industrial CMOS processes with patented micro-machining (CMOSens® technology) ensures highest reliability and excellent long term stability. The device includes a capacitive polymer sensing element for relative humidity and a bandgap temperature sensor. Both are seamlessly coupled to a 14bit analog to digital converter and a serial interface circuit on the same chip. This results in superior signal quality, a fast response time and insensitivity to external disturbances (EMC) at a very competitive price. Each SHTxx is individually calibrated in a precision humidity chamber with a chilled mirror hygrometer as reference. The calibration coefficients are programmed into the OTP memory. These coefficients are used internally during measurements to calibrate the signals from the sensors.
The 2-wire serial interface and internal voltage regulation allows easy and fast system integration. Its tiny size and low power consumption makes it the ultimate choice for even the most demanding applications.
The device is supplied in either a surface-mountable LCC (Leadless Chip Carrier) or as a pluggable 4-pin single-in-line type package. Customer specific packaging options may be available on request.

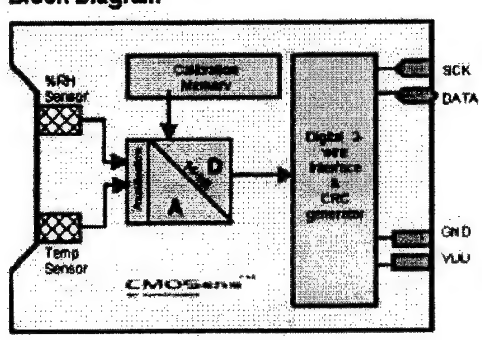
Applications

_ HVAC
_ Automotive
_ Consumer Goods
_ Weather Stations
_ Humidifiers
_ Dehumidifiers
_ Test & Measurement
_ Data Logging
_ Automation
_ White Goods
_ Medical

Ordering Information

Part Number	Humidity accuracy [%RH]	Temperature accuracy [°C]	Package
SHT11	±3.5	±0.5 @ 25 °C	SMD (LCC)
SHT15	±2.0	±0.4 @ 5-40 °C	SMD (LCC)
SHT71	±3.5	±0.5 @ 25 °C	4-pin single-in-line
SHT75	±2.0	±0.4 @ 5-40 °C	4-pin single-in-line

Block Diagram



1 Sensor Performance Specifications

Parameter	Conditions	Min.	Typ.	Max.	Units
Humidity					
Resolution (2)		0.5	0.03	0.03	%RH
		8	12	12	bit
Repeatability			±0.1		%RH
Accuracy (1) Uncertainty	linearized	see figure 1			
Interchangeability		Fully interchangeable			
Nonlinearity	raw data		±3		%RH
	linearized		<<1		%RH
Range		0		100	%RH
Response time	1/e (63%) slowly moving air		4		s
Hysteresis			±1		%RH
Long term stability	typical		< 1		%RH/yr
Temperature					
Resolution (2)		0.04	0.01	0.01	°C
		0.07	0.02	0.02	°F
		12	14	14	bit
Repeatability			±0.1		°C
			±0.2		°F
Accuracy		see figure 1			
Range		-40		123.8	°C
		-40		254.9	°F
Response Time	1/e (63%)	5		30	s

Table 1 Sensor Performance Specifications

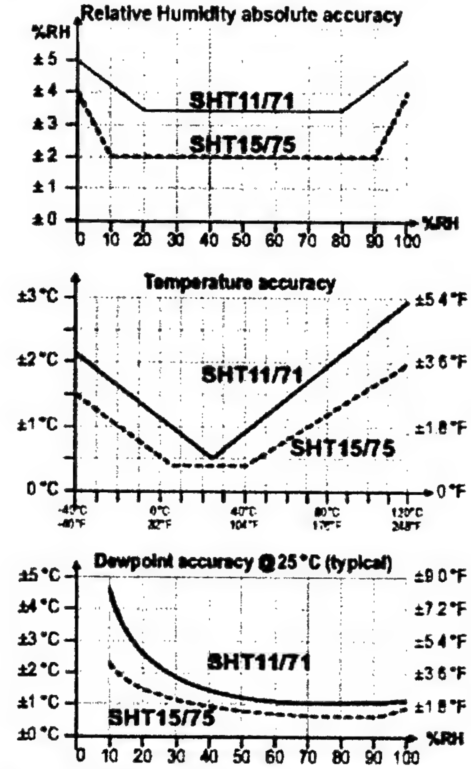


Figure 1 Rel. Humidity, Temperature and Dewpoint accuracies

2 Interface Specifications

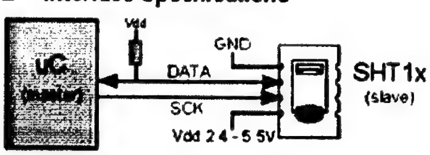


Figure 2 Typical application circuit

2.1 Power Pins

The SHTxx requires a voltage supply between 2.4 and 5.5 V. After powerup the device needs 11ms to reach its "sleep" state. No commands should be sent before that time.
Power supply pins (VDD, GND) may be decoupled with a 100 nF capacitor.

2.2 Serial Interface (Bidirectional 2-wire)

The serial interface of the SHTxx is optimized for sensor readout and power consumption and is not compatible with I²C interfaces, see FAQ for details.

2.2.1 *Serial clock input (SCK)*

The SCK is used to synchronize the communication between a microcontroller and the SHTxx. Since the interface consists of fully static logic there is no minimum SCK frequency.

2.2.2 *Serial data (DATA)*

The DATA tristate pin is used to transfer data in and out of the device. DATA changes after the falling edge and is valid on the rising edge of the serial clock SCK. During transmission the DATA line must remain stable while SCK is high. To avoid signal contention the microcontroller should only drive DATA low. An external pull-up resistor (e.g. 10 kΩ) is required to pull the signal high. (See Figure 2) Pull-up resistors are often included in I/O circuits of microcontrollers. See Table 5 for detailed IO characteristics.

(1) Each SHTxx is tested to be fully within RH accuracy specifications at 25 °C (77 °F) and 48 °C (118.4 °F)
(2) The default measurement resolution of 14bit (temperature) and 12bit (humidity) can be reduced to 12 and 8 bit through the status register

2.2.3 Sending a command

To initiate a transmission, a "Transmission Start" sequence has to be issued. It consists of a lowering of the DATA line while SCK is high, followed by a low pulse on SCK and raising DATA again while SCK is still high.

Figure 3 "Transmission Start" sequence

The subsequent command consists of three address bits (only "000" is currently supported) and five command bits. The SHTxx indicates the proper reception of a command by pulling the DATA pin low (ACK bit) after the falling edge of the 8th SCK clock. The DATA line is released (and goes high) after the falling edge of the 9th SCK clock.

Command	Code
Reserved	0000x
Measure Temperature	00011
Measure Humidity	00101
Read Status Register	00111
Write Status Register	00110
Reserved	0101x-1110x
Soft reset, resets the interface, clears the status register to default values wait minimum 11 ms before next command	11110

Table 2 SHTxx list of commands

2.2.4 Measurement sequence (RH and T)

After issuing a measurement command ('00000101' for RH, '00000011' for Temperature) the controller has to wait for the measurement to complete. This takes approximately 11/55/210 ms for a 8/12/14bit measurement. The exact time varies by up to ±15% with the speed of the internal oscillator. To signal the completion of a measurement, the SHTxx pulls down the data line. The controller must wait for this "data ready" signal before starting to toggle SCK again.

Two bytes of measurement data and one byte of CRC checksum will then be transmitted. The uC must acknowledge each byte by pulling the DATA line low. All values are MSB first, right justified. (e.g. the 5th SCK is MSB for a 12bit value, for a 8bit result the first byte is not used).

Communication terminates after the acknowledge bit of the CRC data. If CRC-8 checksum is not used the controller may terminate the communication after the measurement data LSB by keeping ack high.

The device automatically returns to sleep mode after the measurement and communication have ended.

Warning: To keep self heating below 0.1 °C the SHTxx should not be active for more than 15% of the time (e.g. max. 3 measurements / second for 12bit accuracy).

2.2.5 Connection reset sequence

If communication with the device is lost the following signal sequence will reset its serial interface:

While leaving DATA high, toggle SCK 9 or more times. This must be followed by a "Transmission Start" sequence preceding the next command. This sequence resets the interface only. The status register preserves its content.

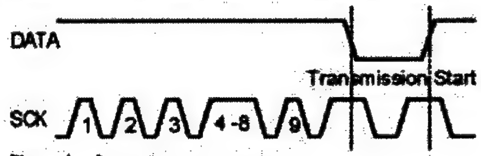


Figure 4 Connection reset sequence

2.2.6 CRC-8 Checksum calculation

The whole digital transmission is secured by a 8 bit checksum. It ensures that any wrong data can be detected and eliminated.

Please consult application note "CRC-8 Checksum Calculation" for information on how to calculate the CRC.

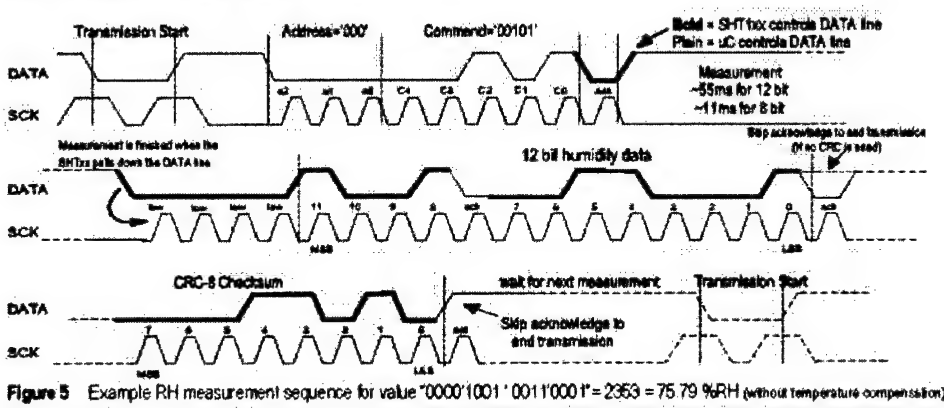


Figure 5 Example RH measurement sequence for value "0000'1001 ' 0011'0001" = 2353 = 75.79 %RH (without temperature compensation)

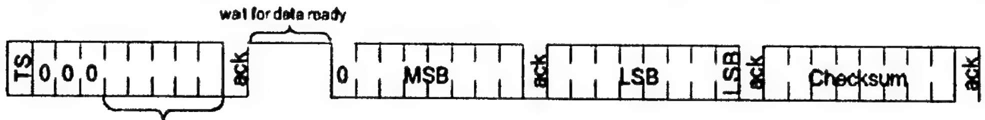


Figure 6 Overview of Measurement Sequence (TS = Transmission Start)

2.3 Status Register

Some of the advanced functions of the SHTxx are available through the status register. The following section gives a brief overview of these features. A more detailed description is available in the application note "Status Register"

Figure 7 Status Register Write

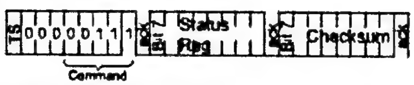


Figure 8 Status Register Read

Bit	Type	Description	Default	
7		reserved	0	
6	R	End of Battery (low voltage detection) '0' for Vdd > 2.47 '1' for Vdd < 2.47	X	No default value, bit is only updated after a measurement
5		reserved	0	
4		reserved	0	
3		For Testing only, do not use	0	
2	R/W	Heater	0	off
1	R/W	no reload from OTP	0	reload
0	R/W	'1' = 8bit RH / 12bit Temperature resolution '0' = 12bit RH / 14bit Temperature resolution	0	12bit RH 14bit Temp

Table 3 Status Register Bits

2.3.1 *Measurement resolution*

The default measurement resolution of 14bit (temperature) and 12bit (humidity) can be reduced to 12 and 8bit. This is especially useful in high speed or extreme low power applications.

2.3.2 *End of Battery*

The "End of Battery" function detects VDD voltages below 2.47 V. Accuracy is ±0.05 V

2.3.3 *Heater*

An on chip heating element can be switched on. It will increase the temperature of the sensor by approximately 5°C (9 °F). Power consumption will increase by ~8 mA @ 5 V.
Applications:
By comparing temperature and humidity values before and after switching on the heater, proper functionality of both sensors can be verified.

- **In high (>95 %RH) RH environments heating the sensor element will prevent condensation, improve response time and accuracy**

Warning: While heated the SHTxx will show higher temperatures and a lower relative humidity than with no heating.

2.4 Electrical Characteristics[1]

VDD=5V, Temperature = 25 °C unless otherwise noted

Parameter	Conditions	Min.	Typ.	Max.	Units
Power supply DC		2.4	5	5.5	V
Supply current	measuring		550		µA
	average	2[2]	28[3]		µA
	sleep		0.3	1	µA
Low level output voltage		0		20%	Vdd
High level output voltage		75%		100%	Vdd
Low level input voltage	Negative going	0		20%	Vdd
High level input voltage	Positive going	80%		100%	Vdd
Input current on pads				1	µA
Output peak current	on			4	mA
	Tristated (off)		10		µA

Table 4 SHTxx DC Characteristics

	Parameter	Conditions	Min.	Typ.	Max.	Units
F_{SCK}	SCK frequency	VDD > 4.5 V			10	MHz
		VDD < 4.5 V			1	MHz
T_{RFO}	DATA fall time	Output load 5 pF	3.5	10	20	ns
		Output load 100 pF	30	40	200	ns
T_{CLx}	SCK hi/low time		100			ns
T_V	DATA valid time			250		ns
T_{SU}	DATA set up time		100			ns
T_{HO}	DATA hold time		0	10		ns
T_R/T_F	SCK rise/fall time			200		ns

Table 5 SHTxx I/O Signals Characteristics

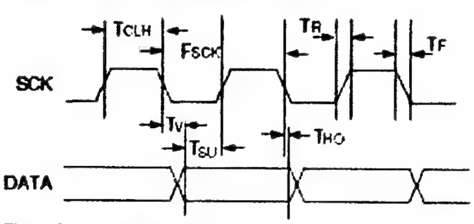


Figure 9 Timing Diagram

[1] Parameters are periodically sampled and not 100% tested
[2] With one measurement of 8 bit accuracy without OTP reload per second
[3] With one measurement of 12bit accuracy per second

3 Converting Output to Physical Values

3.1 Relative Humidity

To compensate for the non-linearity of the humidity sensor and to obtain the full accuracy it is recommended to convert the readout with the following formula[1]:

$$RH_{linear} = c_1 + c_2 \bullet SO_{RH} + c_3 \bullet SO_{RH}^2$$

SO_{RH}	c_1	c_2	c_3
12 bit	-4	0.0405	$-2.8 \cdot 10^{-6}$
8 bit	-4	0.648	$-7.2 \cdot 10^{-4}$

Table 6 Humidity conversion coefficients

For simplified, less computation intense conversion formulas see application note "RH and Temperature Non-Linearity Compensation".

The humidity sensor has no significant voltage dependency.

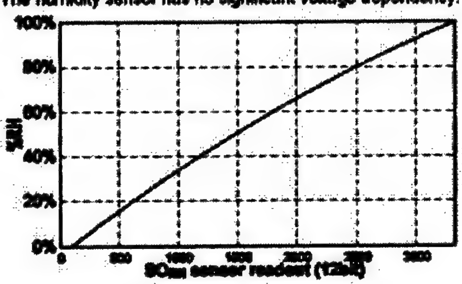


Figure 10 Conversion from SO_{RH} to relative humidity

3.1.1 *Compensation of RH/Temperature dependency*

For temperatures significantly different from 25 °C (~77 °F) the temperature coefficient of the RH sensor should be considered:

$$RH_{true} = (T_{°C} - 25) \bullet (t_1 + t_2 \bullet SO_{RH}) + RH_{linear}$$

SO_{RH}	t_1	t_2
12 bit	0.01	0.00008
8 bit	0.01	0.00128

Table 7 Temperature compensation coefficients

This equals -0.12 %RH / °C @ 50 %RH

3.2 Temperature

The bandgap PTAT (Proportional To Absolute Temperature) temperature sensor is very linear by design. Use the following formula to convert from digital readout to temperature:

$$Temperature = d_1 + d_2 \bullet SO_T$$

VDD	d_1 [°C]	d_1 [°F]
5V	-40.00	-40.00
4V	-39.75	-39.50
3.5V	-39.66	-39.35
3V	-39.60	-39.28
2.5V	-39.55	-39.23

SO_T	d_2 [°C]	d_2 [°F]
14bit	0.01	0.018
12bit	0.04	0.072

Table 8 Temperature conversion coefficients

For improved accuracies in extreme temperatures with more computation intense conversion formulas see application note "RH and Temperature Non-Linearity Compensation".

3.3 Dewpoint

Since humidity and temperature are both measured on the same monolithic chip, the SHTxx allows superb dewpoint measurements. See application note "Dewpoint calculation" for more.

[1] Where SO_{RH} is the sensor output for relative humidity

4 Applications Information

4.1 Operating and Storage Conditions

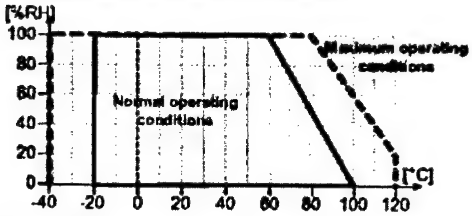


Figure 11 Recommended operating conditions

Conditions outside the recommended range may temporarily offset the RH signal up to ±3 %RH. After return to normal conditions it will slowly return towards calibration state by itself. See 4.3 "Reconditioning Procedure" to accelerate this process. Prolonged exposure to extreme conditions may accelerate ageing.

4.2 Exposure to Chemicals

Vapors may interfere with the polymer layers used for capacitive humidity sensors. The diffusion of chemicals into the polymer may cause a shift in both offset and sensitivity. In a clean environment the contaminants will slowly outgas. The reconditioning procedure described below will accelerate this process.
High levels of pollutants may cause permanent damage to the sensing polymer.

4.3 Reconditioning Procedure

The following reconditioning procedure will bring the sensor back to calibration state after exposure to extreme conditions or chemical vapors.
80-90 °C (176-194°F) at < 5 %RH for 24h (baking) followed by
20-30 °C (70-90°F) at > 74 %RH for 48h (re-hydration)

4.4 Qualifications

Extensive tests were performed in various environments. Please contact SENSIRION for additional information.

Environment	Norm	Results[1]
Temperature Cycles	JESD22-A104-B -40 °C / 125°C, 1000cy	Within Specifications
HAST Pressure Cooker	JESD22-A110-B 2.3bar 125°C 85%RH	Reversible shift by +2 %RH
Salt Atmosphere	DIN-50021ss	Within Spec
Condensing Air	-	Within Spec
Freezing cycles fully submerged	-20 / +90°C, 100cy 30min dwell time	Reversible shift by +2 %RH
Various Automotive Chemicals	DIN 72300-5	Within Specifications
Cigarette smoke	Equivalent to 15years in a mid-size car	Within Specifications

Table 9 Qualification tests (excerpt)

4.5 ESD (Electrostatic Discharge)

ESD immunity is qualified according to MIL STD 883E, method 3015 (Human Body Model at ±2 kV)).
Latch-up immunity is provided at a force current of ±100 mA with T_{amb} = 80 °C according to JEDEC 17.
See application note "ESD, Latchup and EMC" for more information.

4.6 Temperature Effects

The relative humidity of a gas strongly depends on its temperature. It is therefore essential to keep humidity sensors at the same temperature as the air of which the relative humidity is to be measured.
If the SHTxx shares a PCB with electronic components that give off heat it should be mounted far away and below the heat source and the housing must remain well ventilated.
To reduce heat conduction copper layers between the SHT1x and the rest of the PCB should be minimized and a slit may be milled in between. (See figure 14)

4.7 Materials Used for Sealing / Mounting

Many materials absorb humidity and will act as a buffer, increasing response times and hysteresis. Materials in the vicinity of the sensor must therefore be carefully chosen. Recommended materials are:
All Metals, LCP, POM (Delrin), PTFE (Teflon), PE, PEEK, PP, PB, PPS, PSU, PVDF, PVF
For sealing and gluing (use sparingly):
High filled epoxy for electronic packaging (e.g. glob top, underfill), and Silicone are recommended.

4.8 Membranes

A membrane can be used to prevent dirt from entering the housing and to protect the sensor. It will also reduce peak concentrations of chemical vapors. For optimal response times air volume behind the membrane must be kept to a minimum.

4.9 Light

The SHTxx is not light sensitive. Prolonged direct exposure to sunshine or strong UV radiation may age the housing.

4.10 Wiring Considerations and Signal Integrity

Carrying the SCK and DATA signal parallel and in close proximity (e.g. in wires) for more than 10cm may result in cross talk and loss of communication. This may be resolved by routing VDD and/or GND between the two data signals.
Please see the application note "ESD, Latchup and EMC" for more information.
Power supply pins (VDD, GND) should be decoupled with a 100 nF capacitor if wires are used.

[1] The temperature sensor passed all tests without any detectable drift. Package and electronics also passed 100%

5 Package Information

5.1 SHT1x (surface mountable)

Pin	Name	Comment
1	GND	Ground
2	DATA	Serial data, bidirectional
3	SCK	Serial clock, input
4	VDD	Supply 2.4 – 5.5 V
	NC	Remaining pins must be left unconnected

Table 10 SHT1x Pin Description

5.1.1 Package type

The SHT1x is supplied in a surface-mountable LCC (Leadless Chip Carrier) type package. The sensors housing consists of a Liquid Crystal Polymer (LCP) cap with epoxy glob top on a standard 0.8 mm FR4 substrate. The device is free of lead, Cd and Hg.
Device size is 7.42 x 4.88 x 2.5 mm (0.29 x 0.19 x 0.1 inch)
Weight 100 mg

The production date is printed onto the cap in white numbers in the form wwy. e.g. "351" = week 35, 2001.

5.1.2 Delivery Conditions

The SHT1x are shipped in standard IC tubes by 80 units per tube or in 12mm tape. Reels are individually labelled with barcode and human readable labels.

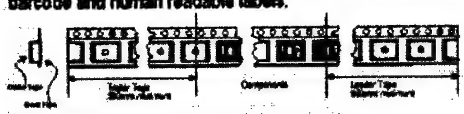


Figure 12 Tape configuration and unit orientation

5.1.3 Mounting Examples

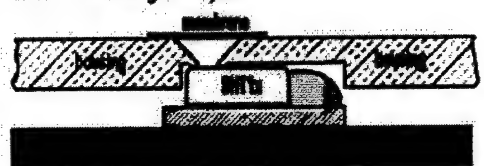


Figure 13 SHT1x housing mounting example

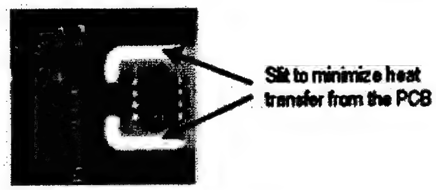


Figure 14 SHT1x PCB Mounting example

5.1.4 Soldering Information

Standard reflow soldering ovens may be used at maximum 235 °C for 20 seconds.
For manual soldering contact time must be limited to 5 seconds at up to 350 °C.
After soldering the devices should be stored at >74 %RH for at least 24h to allow the polymer to rehydrate.
Please consult the application note "Soldering procedure" for more information.

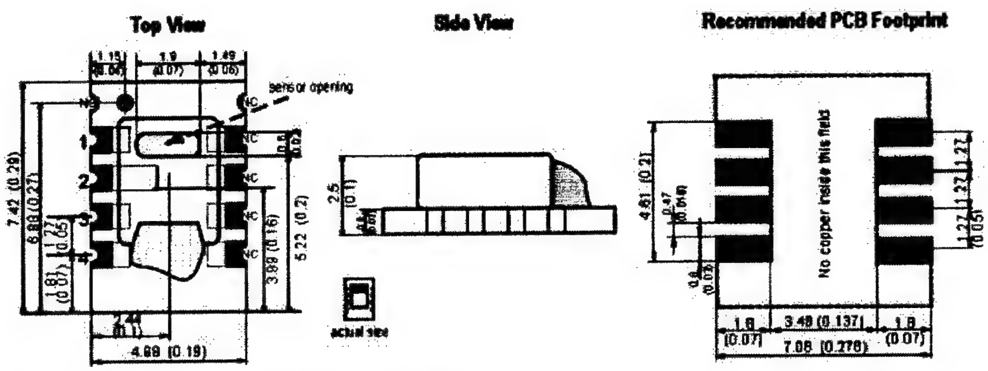


Figure 15 SHT1x drawing and footprint dimensions in mm (inch)

5.2 SHT7x (4-pin single-in-line)

Pin	Name	Comment
1	*SCK*	*Serial clock input*
2	*VDD*	*Supply 2.4 – 5.5 V*
3	*GND*	*Ground*
4	*DATA*	*Serial data bidirectional*

Table 11 SHT7x Pin Description

5.2.1 Package type[1]

The device is supplied in a single-in-line pin type package. The sensor housing consists of a Liquid Crystal Polymer (LCP) cap with epoxy glob top on a standard 0.6 mm FR4 substrate. The device is Cd and Hg free.
The sensor head is connected to the pins by a small bridge to minimize heat conduction and response times. The gold plated back side of the sensor head is connected to the GND pin.
A 100nF capacitor is mounted on the back side between VDD and GND.
All pins are gold plated to avoid corrosion. They can be soldered or mate with most 1.27 mm (0.05") sockets
e.g.: Preci-dip / Mill-Max 851-93-004-20-001 or similar
Total weight: 168 mg, weight of sensor head: 73 mg

The production date is printed onto the cap in white numbers in the form wwy. e.g. "351" = week 35, 2001.

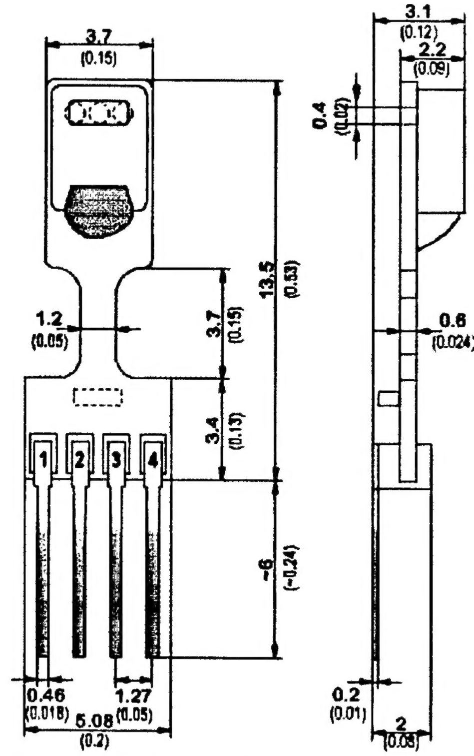


Figure 17 SHT7x dimensions in mm (inch)

5.2.2 Delivery Conditions

The SHT7x are shipped in 32 mm tape. These reeled parts in standard option are shipped with 500 units per 13 inch diameter reel. Reels are individually labelled with barcode and human readable labels.

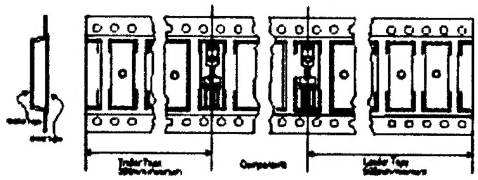


Figure 18 Tape configuration and unit orientation

5.2.3 Soldering Information

Standard wave SHT7x soldering ovens may be used at maximum 235 °C for 20 seconds.
For manual soldering contact time must be limited to 5 seconds at up to 350 °C.
After wave soldering the devices should be stored at >74 %RH for at least 24h to allow the polymer to rehydrate.
Please consult the application note "Soldering procedure" for more information.

[1] Other packaging options may be available on request

6 Revision history

Date	Version	Page(s)	Changes
February 2002	Preliminary	1-9	First public release
June 2002	Preliminary		Added SHT7x information
March 2003	Final v2.0	1-9	Major remake, added application information etc. Various small modifications
	V2.01	1-9	Typos, Graph labeling

The latest version of this document and all application notes can be found at:
www.sensirion.com/en/download/humiditysensor/SHT11.htm

7 Important Notices

7.1 Warning, personal injury

Do not use this product as safety or emergency stop devices or in any other application where failure of the product could result in personal injury. Failure to comply with these instructions could result in death or serious injury.

Should buyer purchase or use SENSIRION AG products for any such unintended or unauthorized application, Buyer shall indemnify and hold SENSIRION AG and its officers, employees, subsidiaries, affiliates and distributors harmless against all claims, costs, damages and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that SENSIRION AG was negligent regarding the design or manufacture of the part.

7.2 ESD Precautions

The inherent design of this component causes it to be sensitive to electrostatic discharge (ESD). To prevent ESD-induced damage and/or degradation, take normal ESD precautions when handling this product.
See application note "ESD, Latchup and EMC" for more information.

7.3 Warranty

SENSIRION AG makes no warranty, representation or guarantee regarding the suitability of its product for any particular purpose, nor does SENSIRION AG assume any liability arising out of the application or use of any product or circuit and specifically disclaims any and all liability, including without limitation consequential or incidental damages. "Typical" parameters can and do vary in different applications. All operating parameters, including "Typical" must be validated for each customer applications by customer's technical experts.

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16. Abstract (Limit: 200 words)

A new relative humidity and air temperature sensor, the Sensirion Model SHT1, has been thoroughly tested by the Upper Ocean Processes (UOP) group at the Woods Hole Oceanographic Institution. One-minute averages from two of the sensors, as well as a Väisälä HMP45A, were recorded for over a year. A third Sensirion sensor was kept in the laboratory and calibrated at monthly intervals with the other three sensors. The standard deviation of the difference in relative humidity between the Sensirion sensors and the Väisälä was about 2%RH. The difference in air temperature was about 0.2ºC. Drift rates in relative humidity for the two Sensirion sensors were 2.7% RH/yr and -0.3% RH/yr, and in air temperature, 0.1ºC/yr and 0/3ºC/yr. Because one of the two Sensirion sensors deployed outside had significant variations in its calibration, the UOP group will not adopt these sensors. However, their very small size, low-cost, and low-power requirements may make them desirable for other uses.

17. Document Analysis a. Descriptors

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air temperature sensor
sensor tests

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

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